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Aeronautical Engineering REVIEW

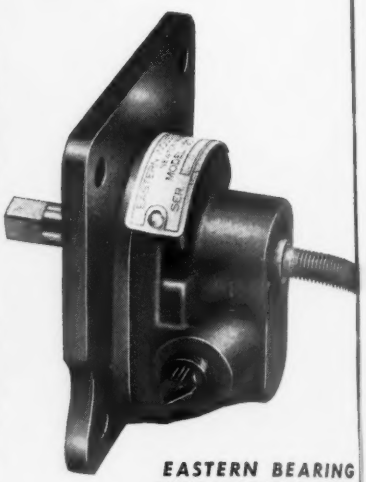
INSTITUTE OF THE AERONAUTICAL SCIENCES
1932 25th ANNIVERSARY 1957

Space Technology

by Lt. Gen. Thomas S. Power, USAF

1957-58 IAS Roster Issue
September, 1957

with smaller, lighter parts



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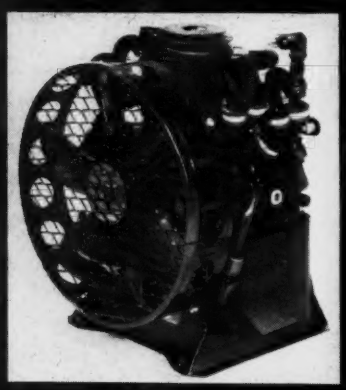

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Vol. 16—No. 9 September, 1957

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Official U.S. Navy photo

Cover—Navy Test Pilot Commander Jack Morrissey flight-tested the B. F. Goodrich Company's new full pressure stratosphere suit in a Chance Vought Crusader recently. Made of rubber and nylon, the suit is said to provide protection at stratosphere altitude and to retain pressure after a pilot bails out. Goodrich says it will also keep him afloat and safe from exposure in cold water. Developed by the firm's Aviation Products Division, the suit is required for protection against loss of cabin pressure at high altitudes.

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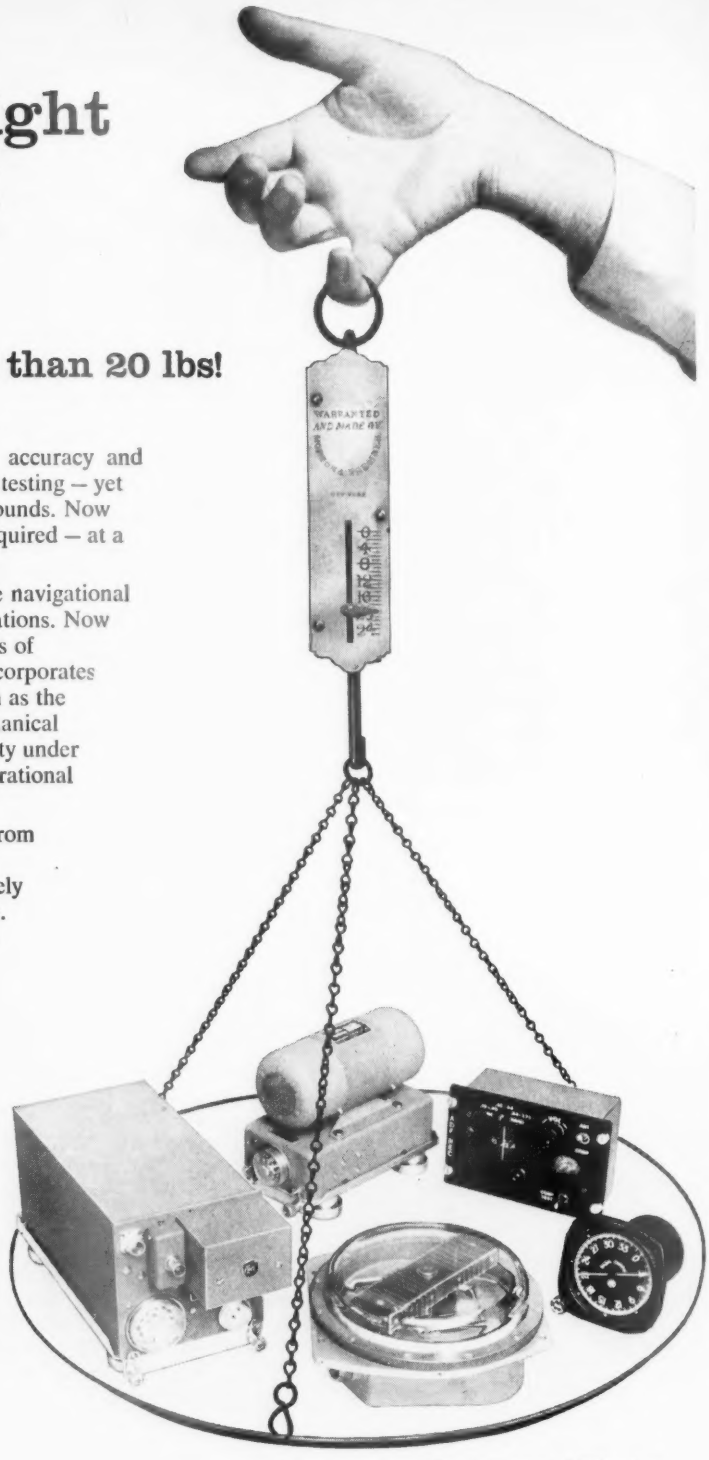

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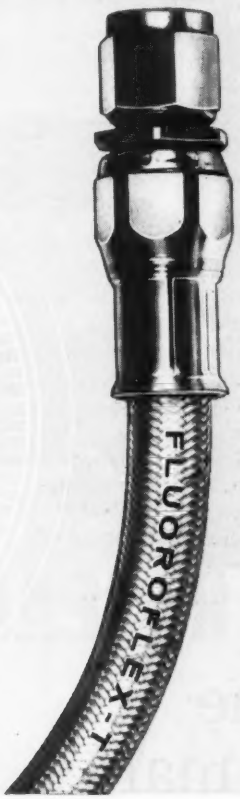

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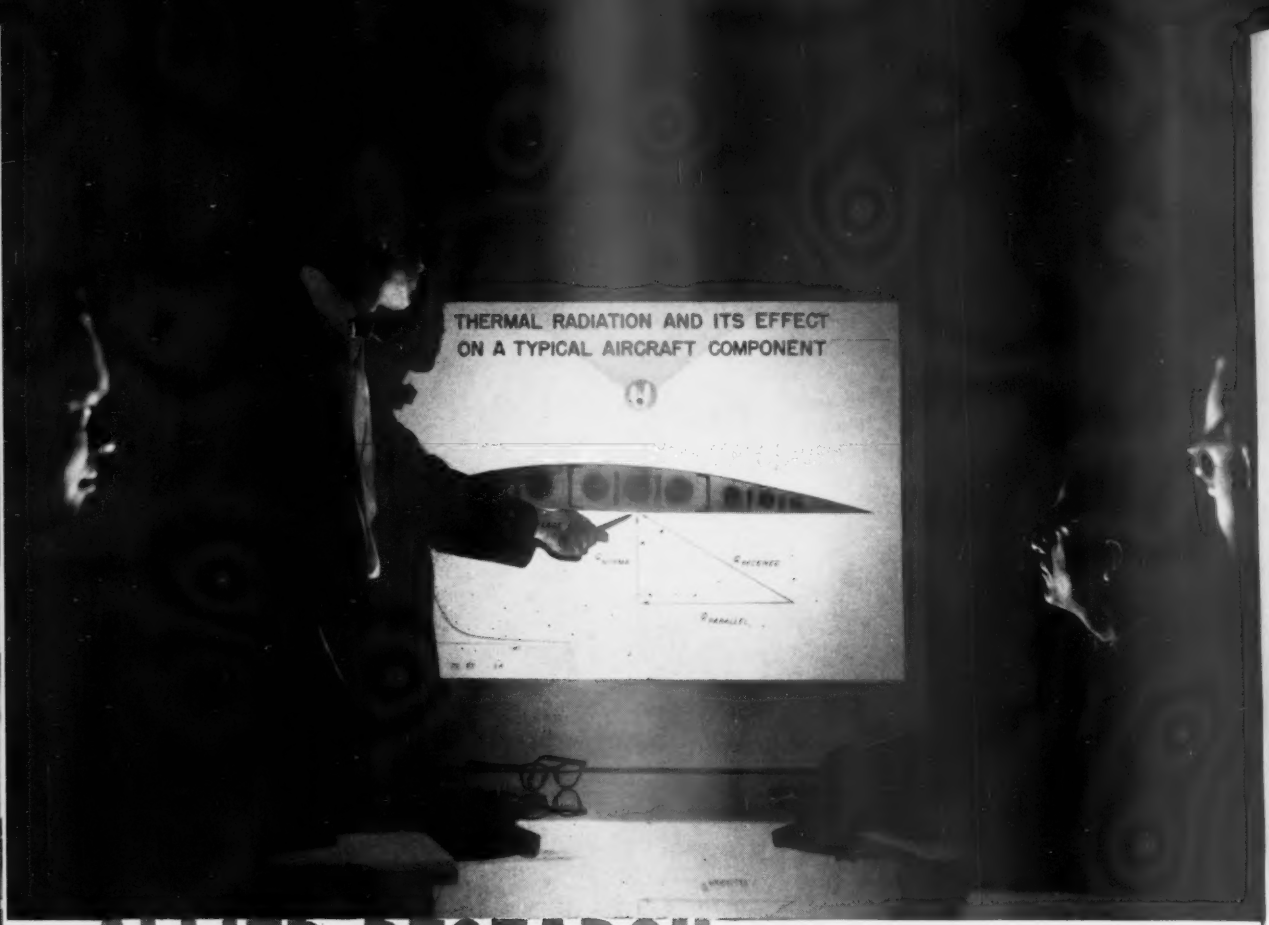

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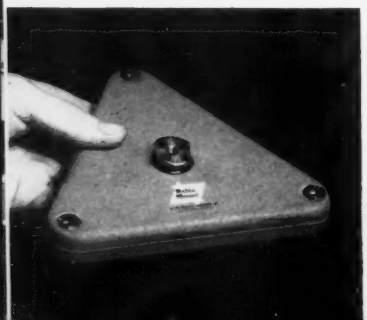

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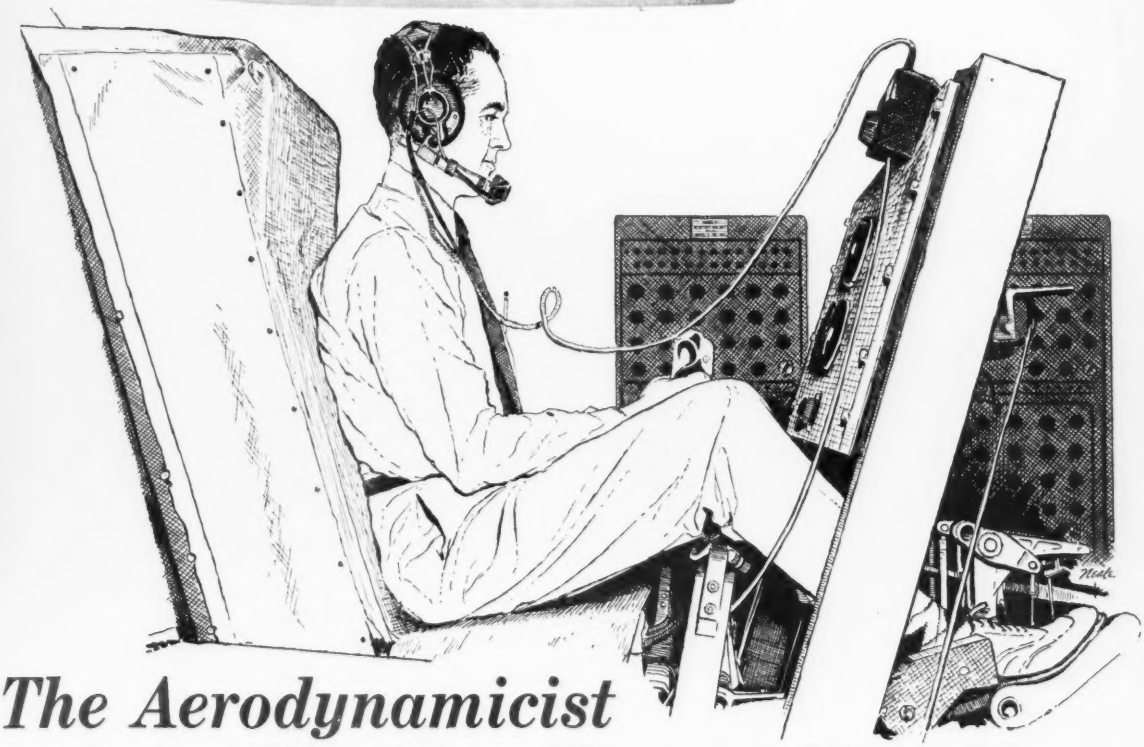

The Aerodynamicist Who Test-Hopped Equations

There'd never been a fighter that could barrel at more than 1,000 mph one minute and land on a carrier the next. And, as a result, there was unusually keen advance interest in the flying qualities of the airplane proposed by Chance Vought.

Jim Madden was more than curious. As an aerodynamic design specialist, he would help develop the Crusader's handling qualities. His job began with wind tunnel tests.

Jim converted tunnel information into a graphic picture of static and dynamic forces affecting Crusader stability. He used analog computers and equations of motion to predict the build-up of forces during maneuvers. Hinge moments, loads, and required rates of control motion were determined and released to Servomechanism and Product Design groups. Soon the Crusader's stabilization and power control packages began to take shape.

Jim's part in the project could have ended right there. But Vought's control system simulator helped him proceed to some thoroughgoing conclusions.

It duplicated the complete rod system and all servomechanisms that would control the speedy new fighter. In the simulator's cockpit, high above the Structures Lab floor, Jim previewed control responses that test pilots later would experience. Airplane responses to Jim's rudder kicks and aileron movements were recorded on analog computers. Any inability of the control system to position the aircraft during flight was easier to spot . . . and, with test and design engineers on hand . . . easier to correct.

"It was like a big schematic — only better," says Jim of the simulator.

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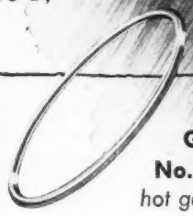

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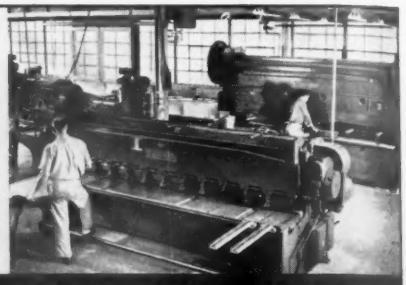

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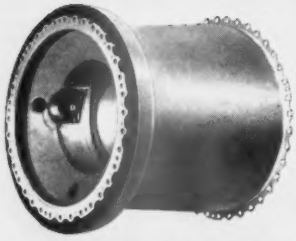

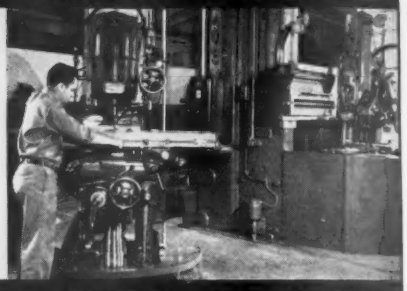

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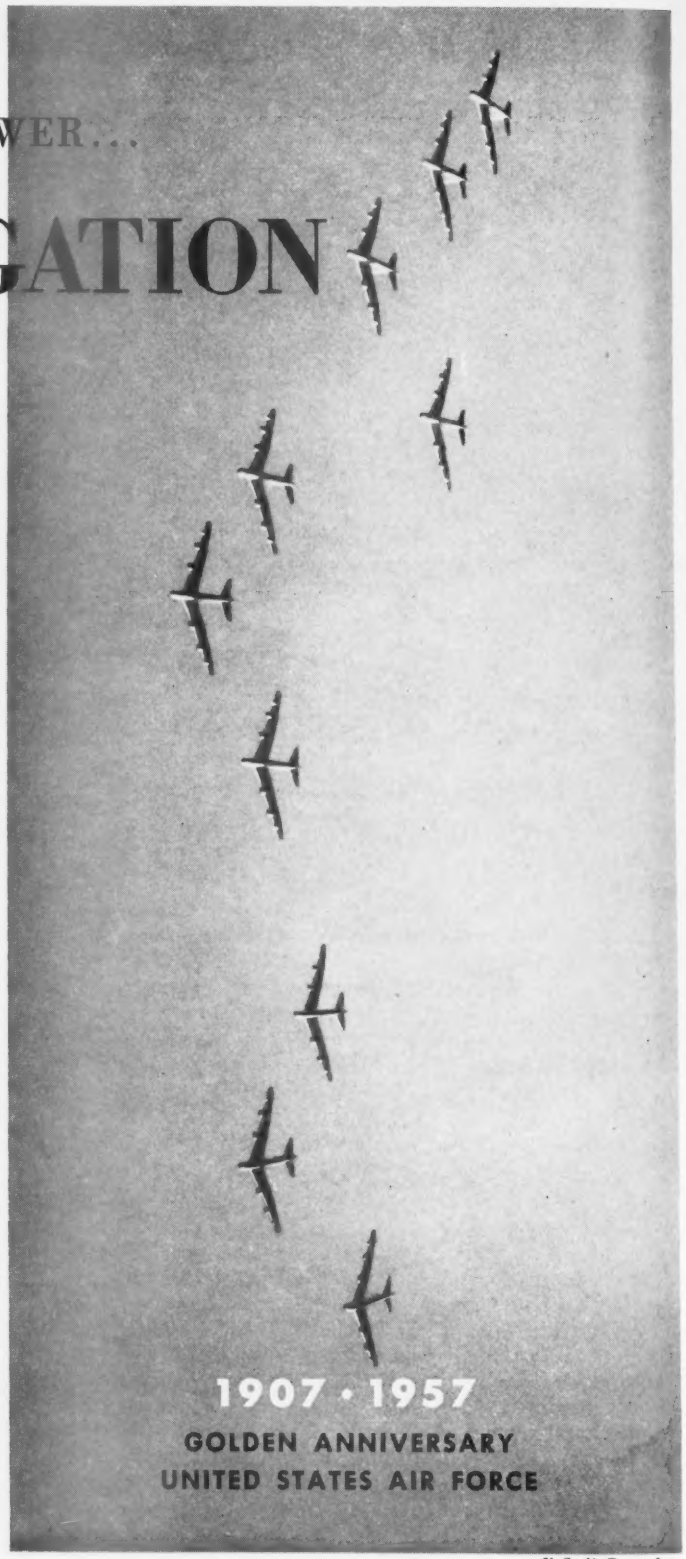

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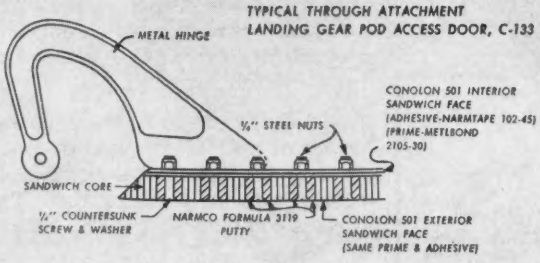
TYPICAL THROUGH ATTACHMENT
LANDING GEAR POD ACCESS DOOR, C-133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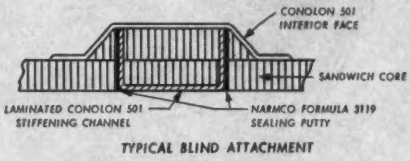
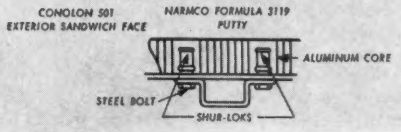


TYPICAL BLIND ATTACHMENT



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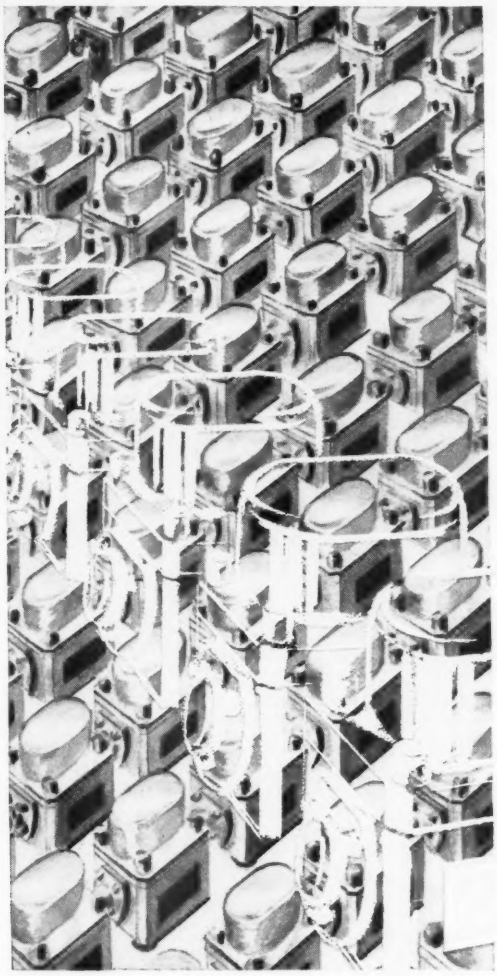

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Much of this equipment is supplied by B. F. Goodrich Aviation Products, where continual research and development is finding new ways to make flying safer, in commercial as well as military operations.

The BFG full-pressure omnienvironment suit at right, for instance, *completely* encloses the pilot from head to toe, provides an artificial environment at any operational altitude. Developed by B. F. Goodrich Aviation Products for the United States Navy, this suit enables a pilot to return safely even if his cockpit should become depressurized. In case of bail out or forced landing on snow or water, it protects him from cold and exposure.

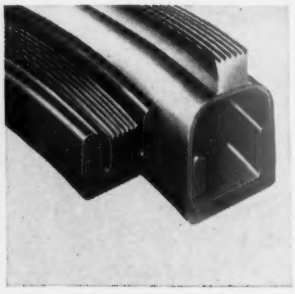
This high altitude suit is only one of many B.F.Goodrich aviation products that contribute to the important program of pilot survival. Several others are shown below. For help in designing specialized equipment to meet the rapidly changing needs of modern aviation, contact:

B.F.Goodrich Aviation Products

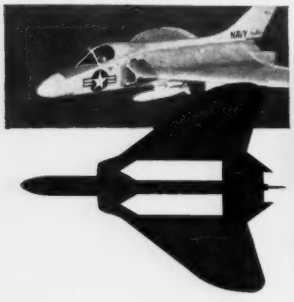
a division of The B.F.Goodrich Company, Akron, Ohio

BFG full-pressure suit provides safe, artificial environment for pilots flying at high altitudes and protects against exposure.

BFG wheels, brakes, tires give maximum efficiency and safety during take-offs and landings.

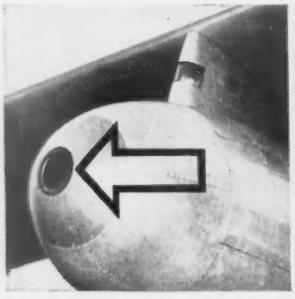


BFG inflatable canopy seals maintain cockpit pressurization, at any altitude...won't blow out.



BFG fuel cells resist high surge pressures by absorbing shock during catapult take-offs.

BFG pneumatic De-Icers provide simple, dependable ice removal for leading edges.



BFG heated rubber prevents plane-crippling ice formations at critical points, such as air intakes.

BFG pressure sealing zipper panels seal asphyxiating jet engine fumes out of cockpit.

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IAS News Notes

September 1957

PROCEEDINGS of the NATIONAL NAVAL AVIATION MEETING, containing all unclassified technical papers, will be available about November 1 from the IAS Special Publications Department - member price - $3.00; nonmember price - $5.00. The story, along with photos, of some of the activities at the San Diego meeting will appear in the October REVIEW.

GORDON R. McGREGOR, (F), President, Trans-Canada Air Lines, will be the principal speaker at the CAI-IAS Meeting and will discuss, "The Economics of Civil Turbine Operations" at the Conference Dinner. Gordon N. Patterson, (F), Director, Institute of Aerophysics, University of Toronto, will deliver the W. Rupert Turnbull Lecture.

THE FOURTH EDITION of First Prize papers given at eight 1957 IAS Regional Student Conferences has been published by the MINTA MARTIN AERONAUTICAL STUDENT FUND under the direction of the Institute. The 128-page volume, "1957 FIRST AWARD PAPERS" contains 12 technical reports (one more than last year) and authors' figures; it will be mailed to Sections, Student Branches, Faculty Advisors and Corporate Member Representatives. Individual requests for copies will be honored while a limited supply lasts.

MEMBERS ARE INVITED to use the IAS National Headquarters Library photocopy service, which provides positive, paper photocopies of technical material. Member rate is $0.40 per 8 1/2" x 11" print, plus postage (nonmember rate: $0.50). Photocopy (and loan) requests are usually filled within 24 hours.

NEW HUNSAKER PROFESSOR: Howard W. Emmons, Harvard University Gordon McKay Professor of Mechanical Engineering and consultant on aerodynamics and thermodynamics, has been appointed to the Jerome Clarke Hunsaker professorship at Massachusetts Institute of Technology for the coming academic year.

WEAPONS SYSTEM MANAGEMENT MEETING planners have set up a program of 15 technical papers and a management panel for the 2-day affair, Nov. 7 and 8. Half the sessions will be classified.

NEWS OF THE DEATH of two members has reached the Institute. Gilbert P. Haven, (M), 37, had been an Experimental Test Pilot for Pratt & Whitney Aircraft Division, United Aircraft Corporation. Captain Claude M. Fligg, (AF), USN (Ret.), died May 6. He had been a Structures Engineer for Lockheed Aircraft Corporation, and was 52.

* * * * * * * *

NATIONAL MEETINGS CALENDAR

Sept. 1-15	Sixth Anglo-American Aeronautical Conference, Royal Aeronautical Society and IAS, London and Folkestone, Great Britain.
Oct. 21-22	Canadian Aeronautical Institute-IAS Meeting, Montreal, Canada.
Nov. 7-8	Weapons System Management Meeting, Statler-Hilton Hotel, Dallas, Texas.
Dec. 17	Wright Brothers Lecture, Washington, D. C.
1958	
Jan. 27-31	Twenty-Sixth Annual Meeting, Sheraton-Astor Hotel, New York.
Mar.13-14	Flight Propulsion Meeting, (Classified), Hotel Carter, Cleveland.
September	First International Congress, International Council of the Aeronautical Sciences, Madrid, Spain.

SECTION MEETINGS CALENDAR

Sept. 10	Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "The Design Development Program for Fatigue Resistance in the DC-8 Structure" by Emerson LaBombard.
Sept. 12	San Diego Section: Specialist Meeting, IAS Building, 8 p.m. "Computer Synthesis and Optimization of Aircraft" by B.F. Mawhinney.
Sept. 17	Kansas City Section: Dinner Meeting, location to be announced. (Social Hour at 5:30, dinner at 6:30) "Development of the Boeing 707" by A. M. (Tex) Johnston.
Sept. 18	Chicago Section: Dinner Meeting, Caffarello's Restaurant, 6:30 p.m. "Commercial Helicopter Operations" by Robert Angstad. Tour of Chicago Helicopter Airways facilities at Midway Airport later.
Sept. 19	Dayton Section: Dinner Meeting, Ember's Supper Club, 6:30 p.m. (Fairborne, Ohio) "The B-58" by J. T. Cosby.
Sept. 19	Washington Section: Dinner Meeting, Occidental Restaurant, 6 p.m. "IGY Satellite Launching Program, Project Vanguard" by J. P. Hagen and D. J. Markasian.
Sept. 19	San Francisco Section: Specialist Meeting, Research Lab., Lockheed Missile Systems Division, Stanford Industrial Park, Palo Alto, 8 p.m. Description and tour of facilities.
Sept. 24	Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Laboratory Magnetohydrodynamics" by Daniel Bershader.
Sept. 25	Detroit Section: Dinner Meeting, Engineering Society of Detroit, Small Auditorium, 6:30 p.m. "Utilization of Jet Engine Bleed Air in Aircraft and the Design and Development of the Bleed Air Control" by R. Schumann and J. F. Hill.
Sept. 27	San Antonio Section: Dinner Meeting, Randolph AFB Officers' Club, 6:30 p.m. "Space Medicine" by James Gaume.

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Painting by Chesley Bonestell from the book *The Exploration of Mars* by Willy Ley, Wernher Von Braun and Chesley Bonestell, published by Viking Press ($4.95). ©C.B.

How do you control temperature on space ships?

The answer is — you don't. The controls do — controls that act many times faster than a man can react. Controls are the real key to all problems beyond sound and heat barriers.

It would be easy to list here the part Fenwal has played in the ever-progressing field of aircraft temperatures, over-heat detection and other controls. But this would only be repetitious. The aircraft industry is well aware of it.

Rather, Fenwal prefers to restate its position for the future. Fenwal is prepared by *experience . . . with equipment . . .* and *through its manpower* to work ahead with you whatever the stage of your current problems. Of this you may be sure: Fenwal's present equipment already enables the most modern advances in its field.

This is well typified by Fenwal's advanced position in power plant controls through thermocouples, harnesses and special engine accessories.

To enlist Fenwal's ability to help meet *your* present and future control problems, write Fenwal Incorporated, Aviation Products Division, Ashland, Massachusetts.

Fenwal *Controls Temperature . . . Precisely*

THERMOCOUPLES TAKE JET'S TEMPERATURE

Fenwal Harness Is Foolproof, Has Long Life

ASHLAND, MASS. — One mechanic who'd never seen Fenwal's Jet Engine Harness before installed it properly in fifteen minutes.

A fool would need a few minutes more to do the trick, but he'd have to be an idiot to get it on wrong. Fenwal makes the harness, which senses a jet's exhaust temperature with thermocouples, as simple as it can possibly be. It can be used for indication, control, or, with certain inexpensive modifications, for both.

The service-life of the harness is at least hundreds of hours in excess of Government specifications. The actual life can only be given as more than a thousand hours, since field tests were called off at that point, with absolutely no signs of failure apparent.

Fenwal pre-forms the harness to fit your engine, and the installer simply slips it around the tail cone. Only two bolts for each thermocouple lock the thermocouple to the harness and the harness to the mounting boss. All thermocouples are keyed, so that they can be installed only in the proper way.

Terminal studs have been eliminated — and vibration-induced breakage and short circuiting have been eliminated too. In place of studs are curved buttons on the thermocouples and flat buttons on the harness. These buttons make the contact between the thermocouple and the harness.

As for maintenance, nothing could be simpler. If it ever becomes necessary to replace a thermocouple, only two bolts are involved. Since the contact buttons are exposed to air flow, removal of moisture and foreign particles from them is virtually automatic. The harness itself needs no care, since it is sheathed in stainless steel, and the bus bars are insulated with a special hard asbestos.

RELIABLE AND FOOLPROOF — This Fenwal Jet Engine Harness senses jet engine temperatures with interchangeable thermocouples for indication and control purposes. It is exceedingly simple to install. It has been service tested for 1000 hours without failures.

You don't have to worry about the effects of differential expansion on the harness, either. The assembly is semi-flexible, and puts only light stresses on the bosses. The bosses don't have to be "beefed up."

The system performs at ambient temperatures up to 1200°F, and Fenwal is prepared to make systems for higher temperatures on request.

It is remarkably light. A four-thermocouple system with a 21-inch diameter harness, for instance, weighs only 3.6 pounds, bolts and all.

You will have no trouble integrating the system with your own indicator or control schemes, or both. The circuitry is simple, too, with balancing resistors in the thermocouple mounting pads for maximum control accuracy. Tolerances are such that no adjustments are needed when a thermocouple is replaced.

Contact your local Fenwal Sales Engineer, or write to Fenwal direct to learn how this system and other widely useful Fenwal concepts can solve temperature control problems now facing you. **Fenwal Incorporated, Aviation Products Division, 178 Pleasant Street, Ashland, Mass.**

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CONTROLS TEMPERATURE ...PRECISELY

IAS News

A Record of People and Events of Interest to Institute Members

CAI-IAS Conference Blueprint Calls for 16 Technical Papers

Fourth Annual "Across-the-Border" Meeting Set for October 21, 22

A SCIENTIST who was elected an IAS Fellow last year will deliver the W. Rupert Turnbull Lecture at the Fourth Annual CAI-IAS International Meeting, October 21, 22, at Montreal's Sheraton-Mount Royal Hotel.

Gordon N. Patterson (F), Director, University of Toronto, Institute of Aerophysics, will speak on "Aerophysical Problems of Flight at Extreme Altitudes and Speeds."

Principal Speaker at the Conference Dinner will be Gordon R. McGregor (F), President, Trans-Canada Air Lines. He will discuss "The Economics of Civil Turbine Operation." The Turnbull Lecture was established to perpetuate the memory of one of Canada's outstanding aviation pioneers and benefactors.

A varied program of 16 technical papers, being organized by Canadian Aeronautical Institute and IAS staff members, will be presented at seven sessions during the two days.

▸ **Morning Session, October 21**—*Navigation and Air Traffic Control:* "Global Navigation in High-Speed Aircraft" by W/C K. R. Greenaway, RCAF; "Flying the Jet Stream" by P. R. J. Reynolds, Chief Navigator, Pan American World Airways, Atlantic Division; and "Jet Weather—A Review of Current Trends in the Provision of Meteorological Service for Aviation . . ." by P. D. McTaggart-Cowan, Department of Transport.

Propulsion: "Recent Advances in the Aerodynamic Design of Axial-Turbo Machinery" by William M. Robbins and Henry W. Plohr, Research Scientists, Lewis Flight Propulsion Laboratory, NACA; "Gas Turbine Combustion System Design" by F. D. M. Williams, Orenda Engines Limited; and a paper on rocket engines for the Vanguard vehicle.

▸ **Afternoon Session, October 21**—*W. Rupert Turnbull Lecture.*

▸ **Morning Session, October 22**—*Education and Training:* Panel discussion, A. E. Ades, Trans-Canada Air Lines; W. A. B. Saunders, Provincial Institute of Technology & Art, Calgary; Winfield H. Arata, Jr., Chief Operations Engineer, Fairchild Aircraft Division, Fairchild Engine & Airplane Corporation; and Courtland D. Perkins, Chief Scientist, USAF.

▸ **Morning Session, October 22**—*Special Techniques:* A paper on the Ryan Vertijet by Earl R. Hinz; paper on flight training on simulators by Capt. G. B. Lothian and D. J. Woodard, Trans-Canada Air Lines; and "Standby Rocket Engines for Civil Aircraft" by G. Edward Rice, Manager, Commercial JATO Sales, Aerojet-General Corporation.

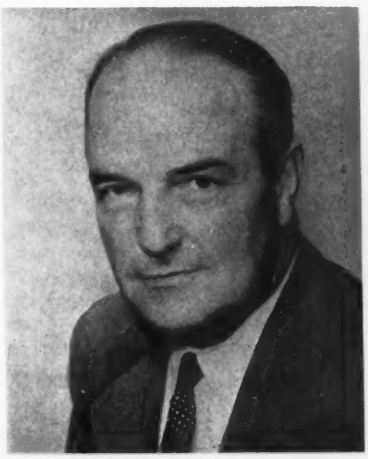
▸ **Afternoon Session, October 22**—*Air-Line Operations:* A paper to be announced; "When Is an Aircraft a 'Nuisance' in the Eyes of the Law?" by A. R. Paterson, Blake, Cassels & Graydon law firm; and "Scheduled Helicopters—The Year 1960" by Robert L. Cummings, Jr., President, New York Airways, Inc.

Space Vehicles: "Project Vanguard—Report of Progress" by Haggai Cohen, Quality Control Manager, Project Vanguard; "Composition of the Upper Atmosphere" by Dr. G. Herzberg, National Research Council; and a third paper on exit and re-entry problems.

Gordon N. Patterson

Group Captain H. R. Foottit, RCAF
1957 CAI President

Gordon R. McGregor
Principal Speaker



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Seventh Annual West Coast Regional Student Conference Draws 150 Students and Faculty Advisers to Los Angeles

Some 150 students and faculty advisers from seven universities attended the Seventh Annual West Coast Regional Student Conference at the IAS Los Angeles Building May 2 and 3. The Los Angeles Section was sponsor.

Nine undergraduate and four graduate papers were presented during the Student Paper Competition.

First prize in the Graduate Division went to William Craig Reynolds, Stanford University, for his paper "Heat Transfer in the Turbulent Boundary Layer With Variable Wall Temperature." Second prize was won by Benjamin E. Cummings, California Institute of Technology, for "Supersonic Flutter of a Thin Elastic Plate Consisting of Many Bays in the Spanwise Direction."

In the Undergraduate Division, Robert L. Balch, Jr., Oregon State College, won first prize for a paper on "An Experimental Method for Determining the Critical Load of an Elastic Column by Measurement of Variation of Frequency of Vibration with Axial Load."

Robert C. Erickson, California State Polytechnic College, won second prize for "A Simplified Shock Tube for Aerodynamic Studies."

Competition judges were Milton Clauser, Director, Aeronautical Research Laboratory, The Ramo-Wooldridge Corporation; William Pennington, Member, Technical Staff, Ramo-Wooldridge; and Donald Warner, Chief of Structures, Northrop Aircraft, Inc.

Los Angeles Section Chairman Welko Gasich welcomed students and faculty members on the morning of May 2, after which the judges were introduced and the paper presentation begun. William Reynolds acted as Student Chairman.

A noon luncheon was sponsored by Servomechanisms, Inc. Later, students visited the Burbank facility of Lockheed Aircraft Corporation where they examined the F-104 assembly line, engineering flying test bed, and Hall of Giants.

Robert L. Balch, Jr.
First-Prize Winner, Undergraduate Division

After a buffet supper sponsored by Douglas Aircraft Company, more technical papers were read. This session was under Student Chairman Robert Parker, Northrop Aeronautical Institute.

The May 3 schedule began with graduate papers presented in the morning under Student Chairman Leland H. Beckwith, California Polytech. Luncheon was sponsored by Hughes Aircraft Company, after which conferees visited North American Aviation's Rocketdyne Division. A rocket test firing at the division's Santa Susanna test facility was seen.

Lieutenant Gen. Laurence Craigie, USAF (Ret.), was toastmaster at the Awards Banquet in the evening. Guests and Section officers present included Mr. Gasich; George Mellinger, Past Section Chairman; Roy Marquardt, President, Marquardt Aircraft Company; Charles Bannan, Vice-President, Western Gear Corporation; E. W. Robischon, IAS Western Region Manager; Frank Washburn, Chairman, Section Student Affairs Committee; and Ronald C. Hinman, Marketing Manager, Western Gear.

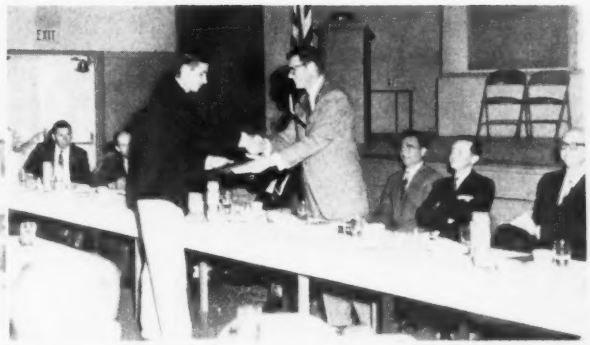
Guest speaker Tony LeVier, Director, Flying Operations, Lockheed, delivered an inspirational talk in which he described himself as "a living example of good engineering."

Other papers presented were: Graduate Division—"Aerodynamic Design of a Variable Geometry Diffuser for a Proposed Hypersonic Wind Tunnel" by Wesley B. Morgan, University of Washington; and "Measurement of Periodic Disturbances in Incompressible Flow" by Daphne Christensen, University of Southern California.

Undergraduate Division—"A Comparison of Adhesive Bonded and Conventional Riveted Beam Construction" by R. P. Bryant, California State Polytechnic College; "The Water Table as a Research Tool in Viscous Flow" by Dale R. Compton, Stanford; "Use of Monographs in Performance Analysis of Airplanes" by Don H. Lesney, Northrop Institute; "Design Analysis of a Liquid Fuel for a Rocket Power Plant" by William Lowe, San Diego State College; "The Relation Between Rivet Detrusion and Progress of Rivet Joint Failure" by R. L. Geib, California Poly; "The Design and Development of a Wind Turbine-Powered Tethered Rotary-Winged Aircraft" by Jack Dwight Dennon, Oregon State; and "Propulsion System for Space Travel" by Norman Huff, San Diego State.

Frank Washburn, *Chairman*
Los Angeles Section
Student Affairs Committee

Left: **William C. Reynolds of Stanford University was presented with first prize in the Student Paper Competition Graduate Division by Milton Clauser, Director, Aeronautical Research Laboratory, The Ramo-Wooldridge Corp.** ***Right:*** **First prize in the Undergraduate Division was awarded to Robert L. Balch, Jr., Oregon State College, by Donald Warner, Chief of Structures, Northrop Aircraft, Inc.**



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The result is true co-ordination of aircraft electrical projects. It must be housed *under one roof* to provide short lead time, prompt delivery and top quality and reliability.

Perhaps Jack & Heintz synergism is the reason why we produce the widest range of aircraft systems and equipment available from any single source under our one roof.

We invite your inquiry. Write to Jack & Heintz, Inc., 17632 Broadway, Cleveland 1, Ohio.

JACK & HEINTZ AIRCRAFT SYSTEMS AND EQUIPMENT

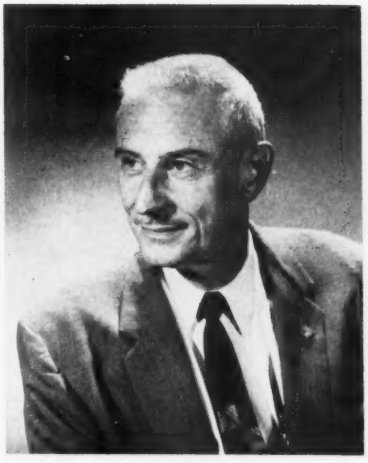
John B. Parkinson Named Recipient of 1957 Water-Based Aviation Award

The Institute's 1957 Water-Based Aviation Award will be presented to John B. Parkinson, Chief, Hydrodynamics Division, Langley Aeronautical Laboratory, NACA, for "sustained leadership in research on the hydrodynamics of water-based aircraft." He will receive the award at the National Naval Aviation Meeting, August 5–10, in San Diego, Calif.

The honor was first presented at last year's IAS Annual Meeting to 12 pioneers in water-based aviation. Mr. Parkinson is the first contemporary in the field to receive it.

The award was established in memory of Edwin C. Musick, pioneer of overseas air transport routes, who was killed in 1938 while in command of the first commercial flight from the United States to New Zealand. Designed to stimulate water-based aircraft research and development, the award is "for meritorious work in the design or operation of water-based aircraft leading to advances in performance or utility."

Mr. Parkinson was graduated from the Webb Institute of Naval Architecture in 1929 and joined the NACA technical staff in 1931. Since that time he has been engaged in research to promote



John B. Parkinson

a better understanding of the basic science of hydrodynamics. His objectives are to advance new seaplane concepts and provide basic research information for the design of improved seaplanes and to evaluate and improve the hydrodynamic qualities of specific seaplane designs. He has been Chief, Hydrodynamics Division, since 1946 and is recognized as an international hydrodynamic authority.

Some of the valuable concepts which Mr. Parkinson has had a direct hand in pioneering and advancing are the use of hydroskis, hydrofoils, high-deadrise hull shapes, high length/beam ratio hulls, and favorable longitudinal area distribution for transonic and supersonic seaplanes. He has done hydrodynamic research on the Martin Clippers, Catalinas, Boeing Clippers, Martin Mariners, Convair Sea Dart, and the Martin Sea-Master. In fact, there have no U.S. Navy flying boats in the last 25 years to which he has not contributed heavily.

The Water-Based Aviation Award Committee that chose Mr. Parkinson is composed of Rear Adm. James S. Russell, Deputy Commander-in-Chief, Atlantic Fleet; Hugh L. Dryden, NACA Director; Mundy I. Peale, President, Republic Aviation Corporation, and IAS President; Grover Loening, Aviation Consultant; Jerome C. Hunsaker, Professor of Aeronautical Engineering, Massachusetts Institute of Technology; Capt. Walter S. Diehl, USN (Ret.), Consulting Engineer; and Earl D. Osborn, Board Chairman, Edo Corporation.

La Guardia Airport Redevelopment Affects 4 IAS Corporate Members

Six air lines—four of which are IAS Corporate Members—and the Port of New York Authority have jointly announced plans for redeveloping La Guardia Airport. Corporate Members involved are American Airlines, Inc.; Eastern Air Lines, Inc.; Trans World Airlines; and United Air Lines, Inc.

The announcement said the revamping would cost "at least $32 million." A modern air terminal will be provided for the seven million passengers a year expected by 1965, car parking space will be doubled, the vehicle road system redesigned and rebuilt, and runways 4–22 and 13–31 together with associated taxiways and aprons rehabilitated. The work, which has already begun, will continue in progressive stages to permit uninterrupted service at the airport.

The Port Authority anticipates additional fees from the air lines in the amount of $2.5 million a year. A new agreement is expected to place landing fees upon a basis of landing weight of aircraft in lieu of current monthly schedules of aircraft movements.

Librascope, Incorporated Joins IAS Corporate Membership

Librascope, Incorporated, manufacturer of computer and control devices for guided missiles and aircraft, has become the 153rd Corporate Member in the Institute. Headquarters for this firm are at 808 Western Avenue, Glendale 1, Calif.

Librascope was founded in 1937 by Lewis W. Imm almost, it might be said, to solve the problem of loading an airplane without disturbing its center of gravity. At that time loading was done by guess or by laborious figuring of each article's effect on the center of gravity. Mr. Imm, then an engineer with the Bureau of Aeronautics, Bureau of Air Commerce, developed a device called the weight and balance computer that automatically calculated for the optimum loading of aircraft with respect to center of gravity.

Librascope, since its founding, has performed development work and service for the Navy, its Bureau of Aeronautics, the Air Force, and various aircraft manufacturers.

NEWS OF MEMBERS

▶ **George A. Page, Jr.** (F), Vice-President, Research and Engineering, Aeronca Manufacturing Corporation, has retired from the firm after 45 years in the aircraft industry. He will continue to serve Aeronca as a consultant.

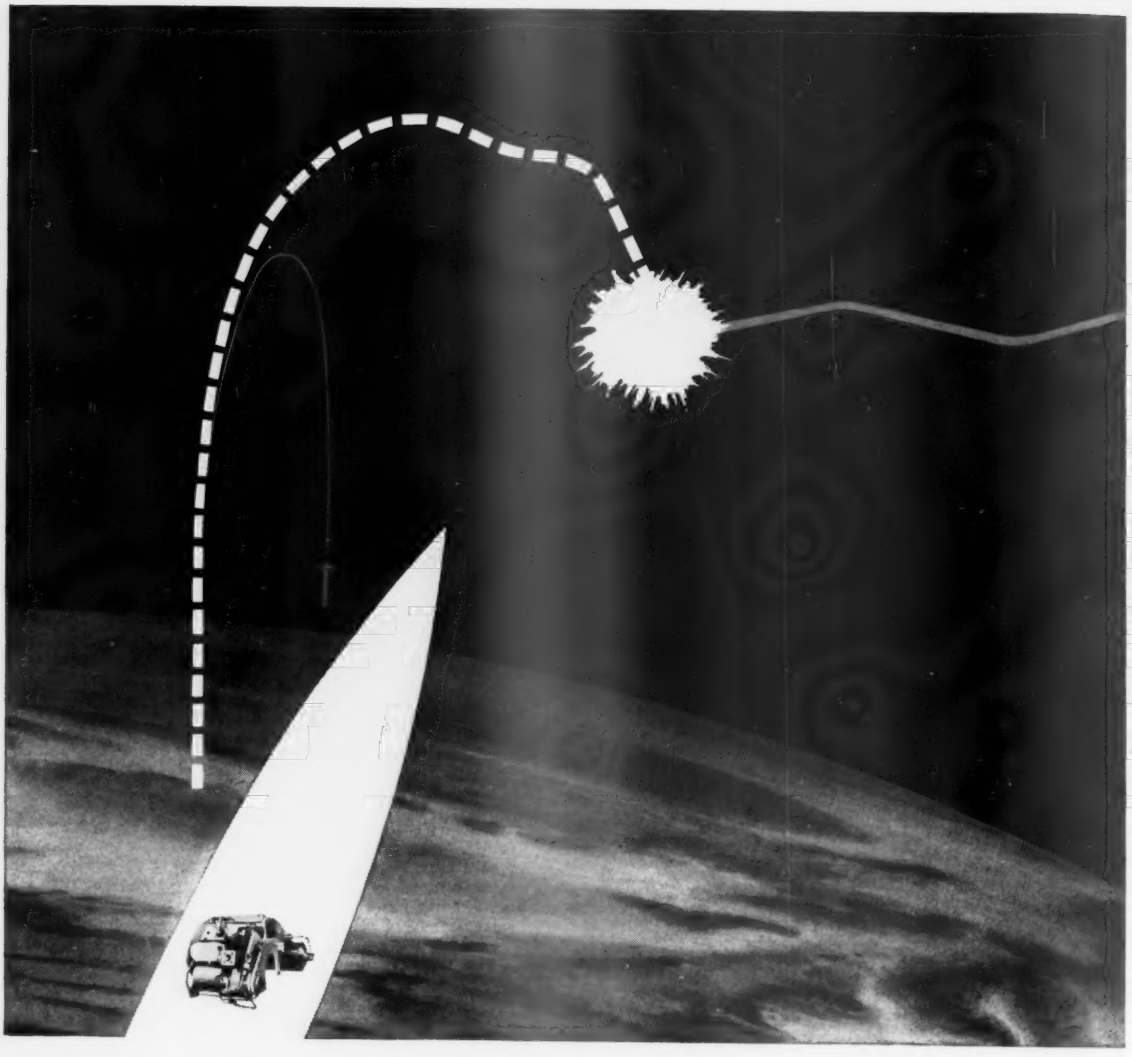
▶ **Edmund T. Price** (M), founder of Solar Aircraft Company and its head for more than 25 years, is retiring as Chairman of the Board and has accepted a professorship of human relations at California Western University.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

John G. Barmby (M) has been promoted to Branch Technical Assistant in

(*Continued on page 90*)



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DATELINE world

PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

Great Utility Predicted by Designer for 'Little Bee'

◆ "Our designing bureau is with great enthusiasm creating a very small aeroplane. We affectionately call it the Little Bee." Thus O. K. Antonov is quoted in an article in the periodical *Soviet Russia*, March 13, 1957.

The article, in direct quotation, continues the noted Russian designer's description of his new short take-off and landing craft:

"This machine caused us a good deal of trouble and called for the solution of most interesting engineering problems. It was necessary to create an airplane for its take-off and landing qualities much resembling a helicopter and in the rest being superior to it. Such an aircraft is needed for rapid communication within a region, for the delivery of mail, small freight, passengers, and for various agricultural jobs. The basic version of the Little Bee, a passenger plane, will resemble a comfortable seven-seater automobile provided with heating and ventilation. It has a minimum speed of 35–40 kilometers per hour and a maximum, over 200 kilometers.

"The Little Bee can land in any field camp, on any rural road, or collective farm thrashing floor. It needs a runway of but 40–60 meters. We want to make this aircraft so simple that it can be piloted by any machine-and-tractor station truck driver or mechanic who has taken a course at an airclub. A most complex task confronted us in designing the Little Bee—to insure automatic safety without automatic instruments, in other words, to foresee in advance the least possibility of danger and eliminate it in designing."

Training of Researchers Progressing in Red China

◆ The Metals Research Institute of the Chinese Academy of Science has established twelve special courses for the training of researchers. The first group of researchers completed three compulsory subjects: Optical Mineralogy, X-Ray Spectrology, and Metallography.

The training program encourages self-study and individual research by trainees and aims to enhance their capacities for analysis and clear and concise reporting. The institute also sends researchers to factories and mines for on-the-job training or advanced research in order to increase their knowledge of production problems. Many of the researchers who have received such on-the-job training are now undertaking steel refining operations or are engaged in experimental production. This program of the Metals Research Institute provides a foundation for the establishment of a new system of academic degrees and fast graduate studies by the Academy of Science.

This is an indication that the Chinese Academy of Science is making progress with its plan to educate one million students over a period of 12 years.

Press, Forging Equipment Industry Berated in U.S.S.R.

◆ Reporting on the major press and forging plants of the U.S.S.R., a Soviet newspaper (*Promyshelenno Ekonomicheskaya Gazeta*, May 16 through July 27, 1956) ran a series of articles on the shortcomings and needs of the Soviet press and forging equipment industry. The journal reported that none of the plants were completing their production quota, and cited major ills of the industry as: lack of building construction, shortage of cranes and manipulators, lack of forgings and castings for building the presses, lack of production plans, inefficient management, and poor quality of workmanship.

The greatest criticism in the articles was aimed at the design bureaus. Several examples supported the charge that blueprints often contained errors. It was also stated that during equipment production numerous modifications had to be performed to correct designs. Instances were mentioned in which as many as 80 to 100 changes were necessary.

These articles are very similar to previous reports on the deficiencies that exist in the Soviet press and forging equipment industry. It appears that the Soviets have recognized the production advantages of presses and forging equipment and are developing a capability to produce such equipment. Although, as the articles emphasize, early in 1956 the U.S.S.R. was having many difficulties in obtaining the desired production, the potential does exist.

Important Strides Recorded With Ceramic Tools by Soviets

◆ An article in the Soviet paper *Promyshelenno Ekonomicheskaya Gazeta*, dated June 10, 1956, discussed the development and utilization of ceramic cutters at a plant in Bakinsk.

This plant had been having difficulty machining with ceramic cutters in that the tips were breaking under the strain of vibration. After experimentation and testing of various angles of inclination, it was found that vibration stopped if the cutter was set one millimeter above the center. With this setting, the workers were able to operate with a spindle speed of 1,200 r.p.m. and cutting rates of 100 to 300 m./min. Following this success they experimented with ceramic cutters on rough casting, and it is reported that they recently succeeded in using ceramic tools to machine rough castings directly from the molds. The article refers to a large quantity of special holders being made for ceramic tips.

From the Soviet literature, it appears that the Soviets are making important strides in the development and utilization of ceramic tools. It is of special interest that they mention advanced tool geometry and special tool holders, since it is believed by some experts that the success of ceramic tools may be dependent upon tool geometry and tool holders rather than the ceramic materials.

Competent Soviet Research in Metals Evidenced by Paper

◆ A Soviet paper by A. I. Stregulin and N. P. Chuprakova, entitled "Effect of Pressure on the Transformation of Austenite to Martensite," reveals competent research applicable to metals in air weapons. Specifically, the paper is concerned with the effect of hydrostatic pressures of up to 12,000 kg./mm.^{2} on the transformation of austenite to martensite in 70G4N4 and 40GN20 steels. Both steels normally have M_s temperatures (the temperature at which martensite begins to form) of about 0°C.

The researchers found that increasing pressure markedly decreased the tem-

(*Continued on page 89*)

EDITORIAL

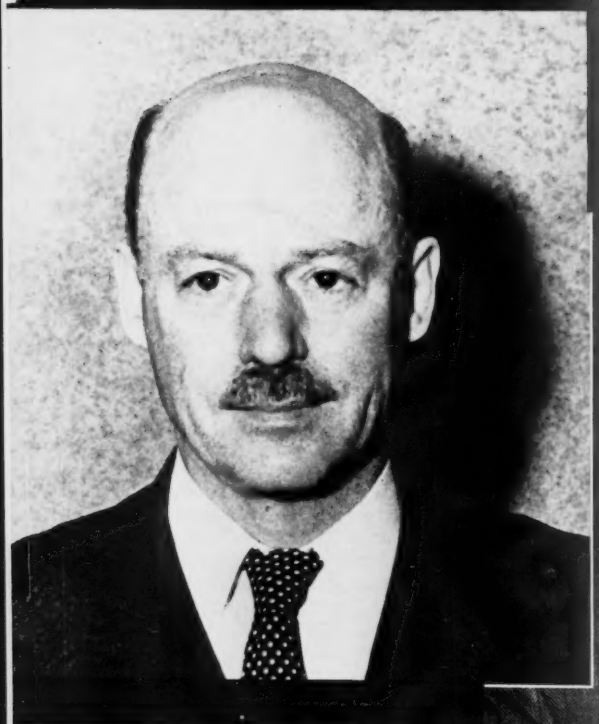
As It Was, in the Beginning . . .

As an organization the IAS is primarily concerned with "the new look," "the forward view," the "forseeable future." As engineers and scientists, we utilize the tools and the building blocks of the present to lay the foundations of the future. For that reason our current programs deal with techniques to improve supersonic aircraft, to design more efficient long-range missiles, and to develop craft of (as yet) unknown configuration to explore the reaches of Outer Space. This is our basic mission. *(Continued on page 31)*

IAS FOUNDER MEMBERS
(Unfold Insert)

Orville Wright
First Honorary Fellow

Some *Famous Firsts*—



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First IAS President

Lester D. Gardner
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Honorary Fellow

Wright, Orville, D. Sc.; Hon. F. I. Ae. S.. (See W. W. in A.)

Scientific Members

Ackeret, J., Dr. Ing.; M. I. Ae. S.; Professor of Aerodynamics, Zurich Technische Hochschule. Switzerland.

Allard, Emile, M. I. Ae. S.; Professor, University of Brussells. Belgium.

Alexanderson, Ernst Frederick Werner, Hon. Dr. Sc.; M. I. Ae. S.; Consulting Engineer, General Elec. Co. (See W. W. in A.)

Altman, Peter, B. Ae. Eng.; M. I. Ae. S.; Prof. of Aeronautical Eng., U. of Detroit. (See W. W. in Eng.)

Ames, Joseph Sweetman, Ph. D.; M. I. Ae. S.; President, John Hopkins University; Chairman, National Advisory Committee for Aeronautics. (See W. W. in A.)

Arnstein, Karl, Dr. Tech. Sci.; M. I. Ae. S.; Vice-Pres. in charge of Engineering, Goodyear Zeppelin Corporation. (See W. W. in A.)

Barnard, Daniel P., D. Sc.; M. I. Ae. S.; Director, Automotive Research, Standard Oil Co. of Ind.

Bateman, Harry, Ph. D.; M. I. Ae. S.; Prof. of Aero. Math. and Theoretical Physics, California Inst. of Technology. (See W. W. in A.)

Betz, Albert, Ph. D.; M. I. Ae. S.; Vice-Direktor, Kaiser Wilhelm Institute for Fluid Motion Research. Goettingen, Germany.

Bevan, Lt. Col. William Alfred, M. Sc.; M. I. Ae. S.; Prof. of Aeronautical Eng., Iowa State College. (See W. W. in A. A.)

Birdsall, Edward T., M. E.; M. I. Ae. S.; Consulting Engr. Lawrance Engineering & Research Corp.

Bjerknes, Vilhelm Trimann Koren, Ph. D.; M. I. Ae. S.; Professor, University of Oslo, Norway. (See Encyclopedia Britannica.)

Blair, Major (U. S. A.) William Richards, Ph. D.; M. I. Ae. S.; Officer in Charge, Signal Corps Laboratories. (See W. W. in A.)

Bairstow, Leonard, F. R. Ae. S.; M. I. Ae. S.; Zaharoff Professor of Aviation, University of London. England. (See B. W. W.)

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Breckenridge, Francis Chapin, M. Sc.; M. I. Ae. S.; Associate Physicist, Bureau of Standards. (See W. W. in Eng.)

Bridgeman, Oscar C., Ph. D.; M. I. Ae. S.; Chief, Lubrication and Liquid Fuels Section, Bureau of Standards. (See A. M. of S.)

Briggs, Lyman James, Ph. D.; M. I. Ae. S.; Director, Bureau of Standards. (See W. W. in A.)

Brombacher, William George, Ph. D.; M. I. Ae. S.; Chief, Aeronautical Instruments Section, Bureau of Stand. (See A. M. of S.)

Brooks, Charles Franklin, Ph. D.; M. I. Ae. S.; Professor of Meteorology and Director of Blue Hill Observatory, Harvard University. (See W. W. in A.)

Burgers, Johannes Martinus, Dr. Math.; M. I. Ae. S.; Professor of Aerodynamics, Delft Technische Hoogeschool. Holland.

Burgess, Charles P., M. I. Ae. S.; Aero. Engineer, Bureau of Aeronautics, Navy Dept.

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Gebers, Friedrich, Dr. Ing.; M. I. Ae. S.; Director, Vienna Schiffbautechnischen Versuchsanstalt. Austria.

Geer, William Chauncey, Ph. D.; M. I. Ae. S.; Research Chemist. (See W. W. in A.)

Georgii, Walter, Ph. D.; M. I. Ae. S.; Professor, Darmstadt Technische Hochschule. Germany.

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Glauert, Hermann, F. R. Ae. S.; M. I. Ae. S.; Principal Scientific Officer, Royal Aircraft Establishment, England. (See B. W. W.)

Glazebrook, Sir Richard Tetley, D. Sc.; F. R. Ae. S.; M. I. Ae. S.; Formerly, Chairman, Advisory Committee for Aeronautics and Director, National Physical Laboratory. England. (See B. W. W.)

Grammel, Richard, Dr. Ing.; M. I. Ae. S.; Prof. of Engineering Mechanics, Stuttgart Technische Hochschule. Germany.

Grant, Hugh Duncan, M. I. Ae. S.; Meteorologist to Armstrong-Dupont Seadromes.

Grard, General Charles, M. I. Ae. S.; Inspector Genetal of Aeronautics and Director of Ecole Nationale Superieure de l'Aeronautique. France.

Gregg, David, M. I. Ae. S.; Research Engineer, Eclipse Aviation Corp. (See W. W. in A. A.)

Gregg, Willis Ray, A. B. (Sc.); M. I. Ae. S.; Principal Meteorologist in charge of Aerological Division, U. S. Weather Bureau. (See W. W. in A.)

Halsted, Arthur, B. Sc.; M. I. Ae. S.; Associate Electrical Engineer, Alternate Chief, Section of Safety, Bureau of Standards. (See W. W. in Eng.)

Hammer, Major William Joseph, M. I. Ae. S.; Consulting Engineer. (See W. W. in A.)

Haslam, Robert Thomas, B. Sc.; M. I. Ae. S.; Vice-Pres. and General Manager, Standard Oil Development Co. (See W. W. in A.)

Haus, Fr. Ch., C. E.; M. I. Ae. S.; Professor of Aerodynamics, University of Ghent; Chief, Belgian Aeronautical Service. Belgium.

Havill, Comdr. Clinton H., M. Sc.; M. I. Ae. S.; Aeronautical Engineer, Eclipse Aviation Corp.

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Jeffries, Zay, D. Sc.; M. I. Ae. S.; Consultant, Aluminum Co. of America. (See W. W. in A.)

Jennings, Dallas Cornwell, M. Chem.; M. I. Ae. S.; Director, Stanavo Specications Board, Inc.

Jones, Bennett Melvill, M. A. (Sc.); F. R. Ae. S.; M. I. Ae. S.; Francis Mond Professor of Aeronautical Engineering, Cambridge University, England. (See

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(Reprinted from the Proceedings of the Founder's Meeting—January 26, 1933)

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McDill, Major (U. S. A.) Leslie, D. Sc.; M. I. Ae. S.; Office, Chief of Air Corps. (See W. W. in A. A.)

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Melan, Joseph, Hon. Dr. Ing.; M. I. Ae. S.; Professor, Prague Technische Hochschule. Czechoslovakia.

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Millikan, Clark Blanchard, Ph. D.; M. I. Ae. S.; Asst. Prof. of Aeronautics, California Inst. of Technology. (See B. B. of A.)

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Mock, Frank Carleton, M. I. Ae. S.; Research Engineer, Bendix Research Corp.

Munk, Max Michael, Ph. D.; M. I. Ae. S.; Lecturer for Aerodynamics, Catholic Univ. of America.

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Nayler, Joseph Lawrence, M. A. (Sc.); F. R. Ae. S.; M. I. Ae. S.; Secretary, Aeronautical Research Committee. England. (See W. W. in B. A.)

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Oseen, Carl Wilhelm, Ph. D.; M. I. Ae. S.; Professor, University of Upsala, Sweden.

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Pegram, George Braxton, Ph. D.; M. I. Ae. S.; Professor of Physics, Columbia University. (See W. W. in A.)

Petavel, Sir Joseph Ernest, D. Sc.; F. R. Ae. S.; M. I. Ae. S.; Director, National Physical Laboratory. England. (See B. W. W.)

Pippard, Alfred John Sutton, D. Sc.; F. R. Ae. S.; M. I. Ae. S.; Professor of Civil Engineering, University of Bristol. England. (See B. W. W.)

Pistolesi, Enrico, Dr. Math.; M. I. Ae. S.; Professor of Applied Mechanics, Royal School of Engineering. Pisa, Italy.

Prandtl, Ludwig, Ph. D.; Hon. F. R. Ae. S.; M. I. Ae. S.; Professor, Goettingen University; Director of Kaiser Wilhelm Institute for Fluid Motion Research. Germany.

Pratt, Haraden, B. Sc.; M. I. Ae. S.; Vice-Pres. and Chief Engineer, Mackay Radio and Telegraph Co. (See W. W. in Eng.)

Prescott, Ford Lewis, M. E.; M. I. Ae. S.; Senior Mechanical Engineer (Research), Power Plant Branch, Material Division U. S. A., Wright Field.

Pye, David Randall, M. A. (Sc.); F. R. Ae. S.; M. I. Ae. S.; Deputy Director of Scientific Research, Air Ministry, England. (See W. W. in B. A.)

Reed, Slyvanus Albert, D. Sc.; M. I. Ae. S.; Propeller Development. (See W W. in A. A.)

Reed, Thomas Roger, M. I. Ae. S.; Senior Meteorologist, San Francisco, U. S. Weather Bureau.

Reichelderfer, Lieut. (U. S. N.) Francis Wylton, M. I. Ae. S.; Bureau of Navigation, U. S. Navy. (See W. W. in A. A.)

Reid, Elliot Gray, M. Sc.; M. I. Ae. S.; Prof. of Aero-

Shaw, Sir (William) Napier, D. Sc.; M. I. Ae. S.; Director, Meteorologist Office (Retired) England. (See B. W. W.)

Smith, Richard Harbert, Ph. D.; M. I. Ae. S.; Professor of Aero. Eng.; Mass. Inst. of Technology. (See A. M. of S.)

Soden-Frauenhofen, Alfred M. Graf von, Dipl. Ing.; M. I. Ae. S.; Directing Manager, Zahnradfabrik. Germany.

Squier, Maj. Gen. (U. S. A. Ret.) George Owen, Hon. D. Sc.; M. I. Ae. S.; Wartime Chief of U. S. A. Air Service, Chief Signal Officer, 1917. (See W. W. in A.)

Stalker, Edward Archibald, M. Sc.; M. I. Ae. S.; Prof. Aero. Eng., Univ. of Mich. (See W. W. in Eng.)

Stedman, Group Captain Ernest Walter, F. R. Ae. S.; M. I. Ae. S.; Chief Aeronautical Engineer, Royal Canadian Air Force. (See W. W. in Eng.)

Suering, Reinhard, Ph. D., M. I. Ae. S.; Meteorologist. Germany.

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Rentschler, Frederick Brant, A. F. R. Ae. S.; President, United Aircraft & Transport Corp. (See W. W. in A.)

Reppy, Alison, Prof. of Law, N. Y. University; Pres., American Academy of Air Law, Editor Air Law Review.

Ripley, Joseph Pierce, M. E.; Vice-Pres., The National City Company, Director, United Aircraft and Transport Corp.

Robertson, Major William Bryan, Vice-Pres., Curtiss-Wright Airplane Co. (See B. B. of A.)

Roe, Sir Alliott Verdon, F. R. Ae. S.; Managing Director, Saunders Roe, Ltd. England. (See B. W. W.)

Russell, Frank Henry, Manager, High-Tensile Division, Edward G. Budd Mfg. Co.; Pres., Manufacturers Aircraft Asso. (See W. W. in A. A.)

Saltus, Rollin Sanford, Jr., Ludington Corp. (See W. W. in A. A.)

Scholle, Howard. Banking. (See W. W. in A. A.)

Schory, Carl F., Hamilton Standard Propeller Co. (See W. W. in A. A.)

Shaw, Benson Russell, M. E.; General Manager, Airport Equipment Co. (See W. W. in Eng.)

Sopwith, T. O. M., F. R. Ae. S.; Managing Director, H. G. Hawker Engineering Co., England. (See B. W. W.)

Spencer, Major Lorillard. (See W. W. in A.)

Sullivan, John Dwight, Lawyer; Member N. Y. State Aviation Com.

Tichenor, Frank A., Publisher, Aero Digest, Sportsman Pilot.

Trippe, Juan Terry, Pres., Pan American Airways.

Trumbull, Hon. John Harper. Member Connecticut State Advisory Board on Aeronautics; Pres., Trumbull Electric Mfg. Company. (See W. W. in A.)

Van Dusen, Charles Albert, Vice-Pres. and Gen. Manager, The Glenn L. Martin Co. (See W. W. in A. A.)

Vaughan, Guy Warner, Pres. and General Manager, Wright Aeronautical Corp. (See W. W. in A. A.)

Victory, John F., Secretary Nat'l Adv. Comm. for Aero. (See B. B. of A.)

Vissering, Harry, Director, Goodyear Zeppelin Corp.

Vosler, Kenneth Davis. Factory Supt. and Treasurer, Edo Aircraft Corp. (See W. W. in A. A.)

Waite, George. Pres., Irving Air Chute Co.

Walsh, Lieut. Col. Raycroft, President, Hamilton Standard Propeller Co. (See W. W. in A. A.)

Webster, Clarence W., Pres., Curtiss-Wright Export Corp.

Wetzel, Harry H., B. Sc.; Vice-Pres. and Gen. Manager, Douglas Aircraft Co. (See W. W. in A. A.)

Wheat, George Seay, Vice-Pres., United Aircraft and Transport Corp. (See W. W. in A.)

Whitney, Cornelius Vanderbilt, Chairman, Pan American Airways Corp. (See W. W. in A.)

Williams, Harvey, B. Sc.; with Wm. B. Nichols & Co.

Wilson, Comdr. Eugene E., M. A. (Sci.), Pres., Chance Vought Corporation. (See W. W. in Eng.)

Winter, Max L., Factory Manager, B/J Aircraft Corp.

Young, William C., B. Sc.; Manager, Aeronautics Dept. Goodyear Tire & Rubber Co. (See W. W. in A. A.)

1932 MEMBERSHIP

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INDUSTRIAL MEMBERS	
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nautical Engineer, The Douglas Aircraft Co. (See W. W. in A. A.)

Knack, Frederick, Ae. E.; M. I. Ae. S.; Consulting Eng.

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Land, Rear Admiral (U. S. N.) Emory Scott, M. Sc.; M. I. Ae. S.; C. R. Ae. S.; Chief of Bureau of Construction and Repair, Navy Dept. (See W. W. in A. A.)

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Ware, Raymond, B. Sc.; M. I. Ae. S.; Consulting Engineer (Aero Engines). (See W. W. in A. A.)

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Wassige, Charles Raymond, M. I. Ae. S.; General and Technical Manager, H. M. D. Farman. France.

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Webb, Lt. Comdr. (U. S. N.) Leland Dotson, M. Sc.; M. I. Ae. S.; U. S. S. Wright. (See W. W. in A A.)

Webster, Commander (U. S. N.) Walter Wynne, M. Sc.; M I. Ae. S.; Head of Airplane Design, Bureau of Aeronautics, Navy Dept. (See W. W. in A. A.)

Weeks, Walter L., M. E.; M. I. Ae. S.; Mech. Engineer, Aircraft Engines, Lawrance Engineering and Research Corp.

Weihmiller, Horace Emil, B. Sc.; M. I. Ae. S.; Aeronautical Engineer. (See W. W. in A. A.)

Westervelt, Captain (U. S. N., Ret.) George, M. Sc.; M. I. Ae. S.; Pres., Intercontinent Aviation, Inc. (See W. W. in A. A.)

Weyerbacher, Comdr. (U. S. N.) Ralph Downs, M. Sc.; M. I. Ae. S.; Chief of Material Division, Bureau of Aeronautics, Navy Department. (See W. W. in A. A.)

White, Will Walter, M. Sc.; M. I. Ae. S.; Research Engineer, Aviation Dept. Standard Oil Co. of N. J. (See W. W. in A. A.)

Wibault, Michel, M. I. Ae. S.; Vice-Pres. and Technical Director, Chantiers Aeronautiques Wibault-Penhoet. France.

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Willgoos, Andrew Van Dean, M. I. Ae. S.; Chief Engineer, Pratt and Whitney Aircraft Co. (See B. B. of A.)

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Zand, Stephen Joseph, Dipl. Eng.; M. I. Ae. S.; Aero-Research Engineer, Sperry Gyroscope, Inc.

Zimmermann, Paul Gerhard, M. E.; M. I. Ae. S.; Consulting Engineer. (See W. W. in A. A.)

Pilot Members

Balchen, Bernt, Test Pilot. (See W. W. in Eng.)

Beard, Myron Gould, Airline Pilot, American Airways.

Bellinger, Comdr. (U. S. N.) Patrick Neison Lynch, Bureau of Navigation, U. S. N. (See W. W. in A. A.)

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Bingham, Hiram, Ph. D.; President, National Aeronautic Association. (See W. W. in A.)

Bragg, Caleb Smith. Director, Bendix Aviation Corp. (See W. W. in A. A.)

Brooks, Capt. Arthur Raymond, B. Sc.; Supervisor, Air Group, Bell Telephone Laboratories, Inc. (See B. B. of A.)

Brow, Lt. Comdr. (U. S. N.) Harold James, Executive Officer, V. T. Squadron 2B A. B. F., U. S. N. (See W. W. in A. A.)

Campbell, Douglas, W. R. Grace & Co.

Carroll, Thomas, Management and Research, Inc. (See W. W. in A. A.)

Chamberlin, Col. Clarence Duncan, Pres., New York and New England Airways, Inc. (See W. W. in A.)

Chandler, Col. (Ret.) Charles de Forest. R. Ae S.; Aeronautic Editor, Ronald Press Co. (See W. W. in A.)

Cleveland, Ephraim Watkins, Test Pilot, Cleveland Pneumatic Tool Co. (See B. B. of A.)

Coffyn, Capt. Frank Trenholm, Early Wright Pilot, with Crouch-Bolas Aircraft Corp. (See B. B. of A.)

Courtney, Francis Thomas, Test Pilot. (See B. B. of A.)

Crosswell, William Jefferson, B. Sc.; Flight Testing and Sales Pilot, Curtiss Aeroplane and Motor Co.

B. of A.)

Hawks, Lt. Comdr. Frank Monroe, Aeronautical Advisor, The Texas Co. (See B. B. of A.)

Jones, Charles Sherman. President, Casey Jones School of Aeronautics. (See B. B. of A.)

Landis, Major Reed G., Chairman, Illinois Aeronautics Commission. (See W. W. in A. A.)

Lott, Egbert Phelps, Vice-Pres. in charge of Operations, National Air Transport.

McAvoy, William Henry, Chief Test Pilot, Natl. Advisory Comm. for Aeronautics.

McClellan, Stephen A., B. Sc.; United Aircraft and Transport Corp.

MacCracken, William Patterson, Jr., Lawyer. (See W. W. in A.)

Macready, Major John Arthur, Manager, Aviation Department, Shell Oil Company. (See B. B. of A.)

Mattern, Col. James J., Test Pilot.

Parkin, Walter F. Jr., Chief Inspector, (Western Division) Aeronautics Branch, Department of Commerce. (See B. B. of A.)

Post, George Birkbeck, Vice-Pres., Edo Aircraft Corporation. (See W. W. in A. A.)

Pratt, Brig. Gen. (U. S. A.) Henry Conger. Assistant Chief, Army Air Corps. (See W. W. in Eng.)

Rittenhouse, Lieut. Comdr. (U. S. N.) David, Naval Aviator.

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Brown, Donald Lamont, Pres., Pratt & Whitney Aircraft Co.

Brukner, Clayton John. Pres. Waco Aircraft Co.

Burden, William Armistead Moale, Aviation Research, Scudder, Stevens & Clark.

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Pilot Members

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Beard, Myron Gould, Airline Pilot, American Airways.

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Bertrandias, Major Victor E. Sales Manager and Chief Test Pilot, General Aviation Mfg. Corp. (See W. W. in A. A.)

Bingham, Hiram, Ph. D.; President, National Aeronautic Association. (See W. W. in A.)

Bragg, Caleb Smith. Director, Bendix Aviation Corp. (See W. W. in A. A.)

Brooks, Capt. Arthur Raymond, B. Sc.; Supervisor, Air Group, Bell Telephone Laboratories, Inc. (See B. B. of A.)

Brow, Lt. Comdr. (U. S. N.) Harold James, Executive Officer, V. T. Squadron 2B A. B. F., U. S. N. (See W. W. in A. A.)

Campbell, Douglas, W. R. Grace & Co.

Carroll, Thomas, Management and Research, Inc. (See W. W. in A. A.)

Chamberlin, Col. Clarence Duncan, Pres., New York and New England Airways, Inc. (See W. W. in A.)

Chandler, Col. (Ret.) Charles de Forest. R. Ae S.; Aeronautic Editor, Ronald Press Co. (See W. W. in A.)

Cleveland, Ephraim Watkins, Test Pilot, Cleveland Pneumatic Tool Co. (See B. B. of A.)

Coffyn, Capt. Frank Trenholm, Early Wright Pilot, with Crouch-Bolas Aircraft Corp. (See B. B. of A.)

Courtney, Francis Thomas, Test Pilot. (See B. B. of A.)

Crosswell, William Jefferson, B. Sc.; Flight Testing and Sales Pilot, Curtiss Aeroplane and Motor Co.

Freeman, Major Talbot Otis, B. Sc.; Associate, Wm. B. Nichols & Co.

Gould, William C., Asst. Manager, United Airports of Connecticut.

Guggenheim, Hon. Harry Frank, D. Sc. (See W. W. in A.)

Haizlip, James Guy, Assistant Director, Aviation Dept., Shell Petroleum Corp.

Hartney, Lieut. Col. Harold Evans. (See W. W. in A. A.)

Havens, Lieut. Comdr. Beckwith, Eastern Factory Representative, Fairchild Airplane Sales Corp. (See B. B. of A.)

Hawks, Lt. Comdr. Frank Monroe, Aeronautical Advisor, The Texas Co. (See B. B. of A.)

Jones, Charles Sherman. President, Casey Jones School of Aeronautics. (See B. B. of A.)

Landis, Major Reed G., Chairman, Illinois Aeronautics Commission. (See W. W. in A. A.)

Lott, Egbert Phelps, Vice-Pres. in charge of Operations, National Air Transport.

McAvoy, William Henry, Chief Test Pilot, Natl. Advisory Comm. for Aeronautics.

McClellan, Stephen A., B. Sc.; United Aircraft and Transport Corp.

MacCracken, William Patterson, Jr., Lawyer. (See W. W. in A.)

Macready, Major John Arthur, Manager, Aviation Department, Shell Oil Company. (See B. B. of A.)

Mattern, Col. James J., Test Pilot.

Parkin, Walter F. Jr., Chief Inspector, (Western Division) Aeronautics Branch, Department of Commerce. (See B. B. of A.)

Post, George Birkbeck, Vice-Pres., Edo Aircraft Corporation. (See W. W. in A. A.)

Pratt, Brig. Gen. (U. S. A.) Henry Conger. Assistant Chief, Army Air Corps. (See W. W. in Eng.)

Rittenhouse, Lieut. Comdr. (U. S. N.) David, Naval Aviator.

Schroeder, Major Rudolph William. Test Pilot and Aeronautical Consultant. (See B. B. of A.)

Shelmerdine, Lieut. Col. Francis Claude, M.; Director of Civil Aviation, Air Ministry. England. (See B. W. W.)

Taylor, James Blackstone, Jr. Pres., Upressit Products Corporation; Test Pilot and Aeronautical Consultant. (See W. W. in A. A.)

Tomlinson, Lt. Comdr. (U. S. N.) Daniel Webb, Assistant to the Pres., Transcontinental & Western Air, Inc. (See B. B. of A.)

Towers, Captain (U. S. N.) John Henry. (See W. W. in A.)

Westover, Brig. Gen. (U. S. A.) Oscar, Asst. Chief of Air Corps, U. S. Army. (See B. B. of A.)

Wheatley, William Ballantine, Chief Test Pilot, Consolidated Aircraft Corp. (See W. W. in A. A.)

White, Henry James, Aviation Representative, Socony-Vacuum, Inc. (See W. W. in A. A.)

Wright, Burdette Shields, E. E.; Vice-Pres., Curtiss-Wright Corp. and Curtiss Aeroplane and Motor Co. (See B. B. of A.)

Young, Hon. Clarence Marshall. Assistant Secretary of Commerce for Aeronautics, Department of Commerce. (See W. W. in A.)

Industrial Members

Adams, Porter Hartwell. Chairman Ex. Comm., National Aeronautics Association. (See W. W. in A.)

Allard, John S. Executive, Curtiss Wright Corporation.

Angell, William Robert, Pres. Continental Motors Corp., and Continental Aircraft Engine Co. (See W. W. in A.)

Asplundh, Edwin T., B. Sc.; Vice-Pres. and General Manager, Pitcairn Autogiro Co.

Barndt, Charles Franklin. Pres. and Gen. Manager, Great Lakes Aircraft Corporation.

Beal, Walter Hubert, B. Sc.; Pres. and General Manager, Lycoming Manufacturing Co.

Beckers, William Gerard, Ph. D.; Manufacturing Chemist. (See W. W. in A.)

Beech, Walter H., Pres., The Beech Aircraft Co.

Bell, Lawrence D., Vice-Pres. and General Manager, Consolidated Aircraft Corp.

Bell, Luther K., General Manager, Aeronautical Chamber of Commerce of America.

Bendix, Vincent, Pres., Bendix Aviation Corp. (See W. W. in A.)

Berchtold, William Edward, Manager, Transport Section, Aeronautical Chamber of Commerce.

Biddlecombe, Conrad Herbert. Instructor in Air Transport, N. Y. University.

Bradley, Samuel Stewart. General Manager, Manufacturers Aircraft Association. (See W. W. in A.)

Breckenridge, Col. Henry, Lawyer. (See W. W. in A.)

Brimhall, Dean R., Ph. D.; Pres., Utah Pacific Airways, Inc. (See A. M. of S.)

Brown, Donald Lamont, Pres., Pratt & Whitney Aircraft Co.

Brukner, Clayton John. Pres. Waco Aircraft Co.

Burden, William Armistead Moale, Aviation Research, Scudder, Stevens & Clark.

Callan, Comdr. John Lansing, Manufacturer. (See W. W. in A. A.)

Aeronautical Corp.

Childs, Geoffrey S. Executive Co. of America.

Cohu, La Motte T., Director,

Davis, Warren Jefferson. Law

Davison, Hon. Frederick Tru Museum of Natural Histo W. in A.)

Deeds, Charles W., B. Sc.; Whitney Aircraft Co.

Deeds, Edward Andrew. Chair United Aircraft and Tra in A.)

Devlin Frank Wesley, M. Sc.; tiss Aeroplane and Motor

De Weese, Bernard D., Vice-P

Doe, Capt. Thomas B., Pres port, Inc. (See B. B. of

Dudley, Shepard, B. Sc.; Ex Specifications Board, Inc.

Dunwoody, Halsey, Col., B. Perry, Martin, Inc. (See

Elliot, Harold A., Vice-Pres. ern Air Transport, Inc.

Emmons, Harold Hunter, Law

Ewing, Hampton, Denman, L tical Committee, Bar Asso

Fairchild, Sherman Mills, M. Aviation Corp. (See W.

Findley, Earl N., Publisher, U

Fleet, Reuben Hollis, Presid Corp. (See B. B. of A.)

Friez, Lucien L., Pres., Julien

Gardner, Major Lester Duran Secretary, Institute of (See W. W. in A.)

Gilmore, William Leslie. Vic ger, Hookless Fastener W. W. in A. A.)

Glazebrook, Otis A., Jr., Cha Aviation Corp.

Glover, Hon. W. Irving. (S

Goldsmith, August, Pres., B.

Goulding, William F., Vice-P Corp.

Grosvenor, Graham Bethune.

Haines, Elmer Burke, Asst. S Aircraft Co.

Hanshue, Harris M., Pres., V

Harpham, F. M., Vice-Pres, ber Co.

Harriman, William Averell, & Co. (See W. W. in A

Hayden, Charles, B. Sc.; Hay W. in A.)

Henderson, Col. Paul. Vice and Transport Co. (See

Hewlett, Palmer Adams, Sal plane and Motor Co.

Hill, Frank Leroy, B. Sc.; Air Associates, Inc.

Hotchkiss, Henry G. Lawy Reports.

Hoyt, Richard Farnsworth, H W. W. in A.)

Hurley, Roy T., C. R. Ae. S send Corp.

Johnson, Edward Albert, Supply Co.

Johnson, Philip Gustav, Pre (See W. W. in A.)

Kellett, W. Wallace, Pres., (See W W. in A. A.)

Kennedy, William Drinkwate Aeronautical Corp.

Lake, Col. Harley W., B. Sc Aviation Dept.

Lees, Robert E., Sales Manag

Lehman, Robert, Lehman Br

Liore, Fernand, Vice-Pres., Olivier, France; Honora dicale des Industries Aer

Litchfield, Paul W., B. Sc.; Rubber Co.; Pres., Goo W. W. in A.)

Loening, Albert Palmer, C. man Aircraft Engineeri A. A.)

Love, Francis H., Pres., Uni

Ludington, C. Townsend, P Inc. (See W. W. in A.

McDonnell, Edward Orrick, Corp.

Marcus, Charles, M. E.; Pres

Mingos, Howard L. Aerona in A.)

Morgan, Thomas A., Pres., American Aviation, Inc ber of Commerce of A

Neville, Leslie E., Managing

Newbold, George. Sales M

Oertel, Robb C., Standard

Osborn, Earl Dodge, A. F Aircraft Corporation.

Palmedo, Roland.. Lehman Air Express.

Corp.
S. Executive Vice-President, Autogiro
erica.
T., Director, General Aviation Corp.
Jefferson. Lawyer. (See W. W. in A.)
Frederick Trubee, President, American
Natural History, New York. (See W.

W., B. Sc.; Vice-Pres., The Pratt &
ircraft Co.
Andrew. Chairman, Executive Committee,
craft and Transport Co. (See W. W.

Jesley, M. Sc.; Asst. Gen. Manager, Cur-
ne and Motor Corp.
ard D., Vice-Pres., Stinson Aircraft Corp.
omas B., President, Eastern Air Trans-
(See B. B. of A.)
d, B. Sc.; Executive Secretary, Stanavo
s Board, Inc.
lsey, Col., B. Sc.; Vice-Pres., Rhodes,
in, Inc. (See B. B. of A.)
., Vice-Pres. and General Manager, East-
nsport, Inc.
Hunter, Lawyer. (See W. W. in A. A.)
n, Denman, Lawyer; Chairman, Aeronau-
ittee, Bar Association, New York City.
an Mills, M. R. Ae. S.; Pres., Fairchild
orp. (See W. W. in A.)
, Publisher, U. S. Air Services.
Hollis, President, Consolidated Aircraft
B. B. of A.)
Pres., Julien P. Friez & Sons.
Lester Durand, B. Sc.; A. F. R. Ae. S.;
Institute of the Aeronautical Sciences.
V. in A.)
n Leslie. Vice-Pres. and General Mana-
less Fastener Co., Meadville, Pa. (See
A. A.)
s A., Jr., Chairman, B. of D., National
orp.
V. Irving. (See W. W. in A.)
ust, Pres., B. G. Corporation.
am F., Vice-Pres., Curtiss-Wright Export

ham Bethune. (See W. W. in A.)
Burke, Asst. Sales Mgr., Pratt & Whitney
.
s M., Pres., Western Air Express.
M., Vice-Pres, Goodyear Tire and Rub-

iam Averell, Brown Brothers, Harriman
e W. W. in A.)
s, B. Sc.; Hayden Stone & Co. (See W.

l. Paul. Vice-President, United Aircraft
port Co. (See W. W. in A.)
r Adams, Sales Manager, Curtiss Aero-
Motor Co.
roy, B. Sc.; Pres. and General Manager,
ates, Inc.
ary G. Lawyer; Editor, U. S. Aviation

Farnsworth, Hayden, Stone & Co. (See
A.)
, C. R. Ae. S.; Vice-Pres., Hurley-Town-

rd Albert, Pres., Johnson Airplane &
.
Gustav, Pres., United Air Lines, Inc.
V. in A.)
llace, Pres., The Kellett Autogiro Corp.
V. in A. A.)
am Drinkwater, Service Manager, Wright
al Corp.
ley W., B. Sc.; Manager, Socony-Vacuum
Dept.
, Sales Manager, Pitcairn Autogiro Co.
t, Lehman Brothers. (See W. W. in A.)
, Vice-Pres., des Etablissements Liore et
ance; Honorary President, Chambre Syn-
Industries Aeronautiques. France.
W., B. Sc.; Pres., Goodyear Tire and
b.; Pres., Goodyear-Zeppelin Corp. (See
A.)
t Palmer, C. R. Ae. S.; Director, Grum-
aft Engineering Corp. (See W. W. in

H., Pres., United Aircraft Exports, Inc.
Townsend, President, Ludington Airlines,
W. W. in A. A.)
lward Orrick, Director, National Aviation

s, M. E.; Pres., Eclipse Aviation Corp.
rd L. Aeronautical Writer. (See W. W.

as A., Pres., Curtiss-Wright Corp., North
Aviation, Inc.; Pres., Aeronautical Cham-
mmerce of America.
E., Managing Editor, Aviation Magazine.
rge. Sales Manager, Aviation Magazine.

C., Standard Oil Co. of N. J.
Dodge, A. F. R. Ae. S.; President, Edo
Corporation. (See W. W. in A. A.)
nd.. Lehman Brothers; Director, Western
ess.

Rentschler, Frederick Brant, A. F. R. Ae. S.; President, United Aircraft & Transport Corp. (See W. W. in A.)

Reppy, Alison, Prof. of Law, N. Y. University; Pres., American Academy of Air Law, Editor Air Law Review.

Ripley, Joseph Pierce, M. E.; Vice-Pres., The National City Company, Director, United Aircraft and Transport Corp.

Robertson, Major William Bryan, Vice-Pres., Curtiss-Wright Airplane Co. (See B. B. of A.)

Roe, Sir Alliott Verdon, F. R. Ae. S.; Managing Director, Saunders Roe, Ltd. England. (See B. W. W.)

Russell, Frank Henry, Manager, High-Tensile Division, Edward G. Budd Mfg. Co.; Pres., Manufacturers Aircraft Asso. (See W. W. in A. A.)

Saltus, Rollin Sanford, Jr., Ludington Corp. (See W. W. in A. A.)

Scholle, Howard. Banking. (See W. W. in A. A.)

Schory, Carl F., Hamilton Standard Propeller Co. (See W. W. in A. A.)

Shaw, Benson Russell, M. E.; General Manager, Airport Equipment Co. (See W. W. in Eng.)

Sopwith, T. O. M., F. R. Ae. S.; Managing Director, H. G. Hawker Engineering Co., England. (See B. W. W.)

Spencer, Major Lorillard. (See W. W. in A.)

Sullivan, John Dwight, Lawyer; Member N. Y. State Aviation Com.

Tichenor, Frank A., Publisher, Aero Digest, Sportsman Pilot.

Trippe, Juan Terry, Pres., Pan American Airways.

Trumbull, Hon. John Harper. Member Connecticut State Advisory Board on Aeronautics; Pres., Trumbull Electric Mfg. Company. (See W. W. in A.)

Van Dusen, Charles Albert, Vice-Pres. and Gen. Manager, The Glenn L. Martin Co. (See W. W. in A. A.)

Vaughan, Guy Warner, Pres. and General Manager, Wright Aeronautical Corp. (See W. W. in A. A.)

Victory, John F., Secretary Nat'l Adv. Comm. for Aero. (See B. B. of A.)

Vissering, Harry, Director, Goodyear Zeppelin Corp.

Vosler, Kenneth Davis. Factory Supt. and Treasurer, Edo Aircraft Corp. (See W. W. in A. A.)

Waite, George. Pres., Irving Air Chute Co.

Walsh, Lieut. Col. Raycroft, President, Hamilton Standard Propeller Co. (See W. W. in A. A.)

Webster, Clarence W., Pres., Curtiss-Wright Export Corp.

Wetzel, Harry H., B. Sc.; Vice-Pres. and Gen. Manager, Douglas Aircraft Co. (See W. W. in A. A.)

Wheat, George Seay, Vice-Pres., United Aircraft and Transport Corp. (See W. W. in A.)

Whitney, Cornelius Vanderbilt, Chairman, Pan American Airways Corp. (See W. W. in A.)

Williams, Harvey, B. Sc.; with Wm. B. Nichols & Co.

Wilson, Comdr. Eugene E., M. A. (Sci.), Pres., Chance Vought Corporation. (See W. W. in Eng.)

Winter, Max L., Factory Manager, B/J Aircraft Corp.

Young, William C., B. Sc.; Manager, Aeronautics Dept. Goodyear Tire & Rubber Co. (See W. W. in A. A.)

1932 MEMBERSHIP

HONORARY FELLOW	1
SCIENTIFIC MEMBERS	
American	117
Foreign	62
ENGINEERING MEMBERS	
American	219
Foreign	36
PILOT MEMBERS	
American	49
Foreign	1
INDUSTRIAL MEMBERS	
American	118
Foreign	3
TOTAL MEMBERSHIP	607

1957 MEMBERSHIP

HONORARY MEMBERS	16
HONORARY FELLOWS	32
FELLOWS	213
ASSOCIATE FELLOWS	1,138
MEMBERS	5,572
ASSOCIATES	5,774
STUDENT MEMBERS	4,397
TOTAL MEMBERSHIP	17,142

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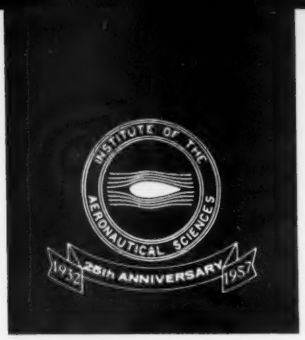


(Continued from page 28)

But occasionally—even in these days when the pressure of the present is on us—it is interesting, perhaps a bit amusing, to steal a backward glance to see how far we have come and how we got from there to here. Inevitable birthdays and anniversaries offer convenient excuses. This is one such occasion.

Founded in the Fall of 1932, the Institute is now rounding out its first 25 years of service. Dr. Clark Millikan of GALCIT, one of our distinguished Past Presidents, in addressing a luncheon at the recent IAS Summer Meeting in Los Angeles, took a backward look at the Institute's first Quarter Century. Although his remarks were not intended originally for publication, they seemed interesting, amusing, and appropriate enough for reproduction in the pages immediately following.

Old Hands will possibly feel a nostalgic twinge at Clark's references to the Good Old Days at Columbia, to the Multi-Bellied Beta, and to Monsieur Picon. Younger Generations (which included most of his audience—and most of our readers) will possibly be confused, bemused, and/or amused at the simple prewar antics of the Old Boys. In any case, it was lots of fun, and out of those (relatively) carefree days came the Institute of the Aeronautical Sciences of 1957.

We owe a debt of gratitude to those who believed enough in the embryo institution of 1932 to join it and to support it. We think enough of them to print their names in the folded insert. This is, in fact, a reprint of the original list of members who *were* the IAS in 1932. It is amazing how many of them are still with us. Time and normal attrition have taken their toll, but an extraordinary number of the original lot may be found in the pages of the Roster Section, which also appears in this issue. It is an interesting game to compare their business connections and positions then and now. Without becoming statistical, we can say that most of today's leaders in aeronautics were Founder Members of this Organization.

And so in this way, we salute the men of our own "Twenty-Five Year Club." We hand them no special buttons to wear, no engraved certificates to hang in their offices—only our profound thanks for their belief in the original idea. They supported us with their time and money when it was needed most. Many of them have since served the Institute well as Officers and Members of the Council. "They made us what we are today." We hope they are satisfied.

S.P.J.

REFLECTIONS ON OUR *First Quarter Century*

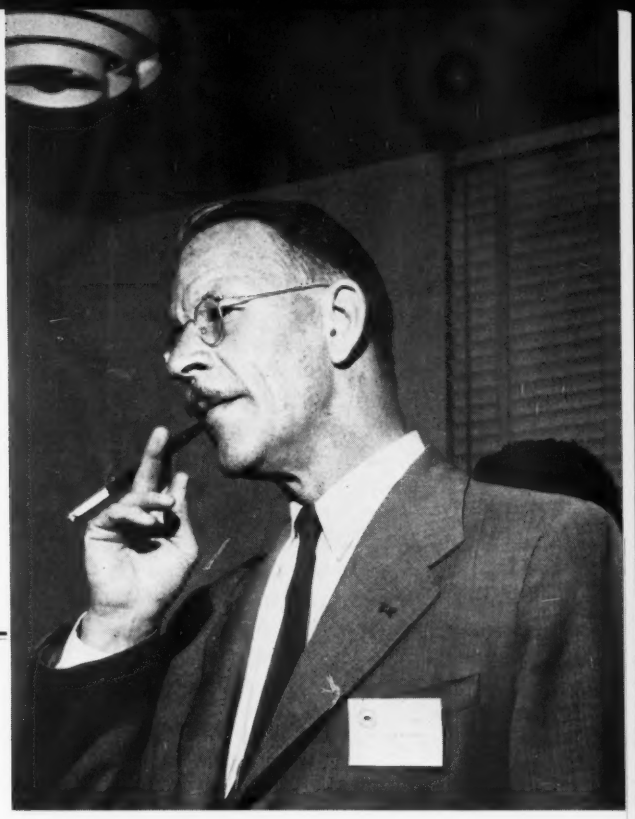
IT IS ALMOST INVARIABLY true that the creation of a new organization or institution begins with a concept brought to focus and to initial realization by one or two far-seeing, courageous, and effective men. The case of the IAS is no exception. Our two men were Dr. Jerome C. Hunsaker and Major Lester D. Gardner. In 1928, feeling that there was in this country an unfulfilled need for a society concerned with the technical and scientific aspects of aeronautics, they wrote to the President of the Royal Aeronautical Society, which for decades had most effectively served just such a purpose for the British aeronautical community. They asked for information on the objectives and the means for their attainment which had proved so successful in England, and they received most generous and detailed replies. It appeared that a society in this country might well be patterned on the British predecessor in many respects. This has, in fact, occurred. The time, however, was not then propitious, and the matter was dropped for nearly 5 years. It was revived in October, 1932 when Hunsaker and Gardner met with Ed Aldrin, Charles Lawrance, Grover Loening, Earl Osborn, and Edward Warner. The group decided to spark-plug the founding of an aeronautical scientific society. Ed Warner suggested the name which was enthusiastically received and has been our official designation ever since. Within less than 2 weeks, by October 15, 1932, the incorporation papers had been drafted, approved, and officially filed in Albany, and the Institute of the Aeronautical Sciences was legally in business. Within a few days the incorporators had met and elected temporary officers and a twelve-man Board of Directors called the Council. Most importantly, they appointed Lester Gardner to be Secretary.

Now Lester could begin exercising the amazing organizational ability, energy, and drive which he devoted for so many subsequent years to the Institute's activities and growth. The office was set up in his home and from it were issued invitations to leaders in aeronautics in the United States and abroad to join the new organization. A Constitution and By-Laws were carefully prepared after diligent research into the

Dr. Millikan's remarks were presented as a luncheon speech at the IAS National Summer Meeting, Los Angeles, Calif., June 17-20, 1957.

"...Past Presidents of the Institute, leaders in science and

1933	1934	1935	1936	1938	1939
J. C. Hunsaker	C. L. Lawrance	D. W. Douglas	G. L. Martin	T. P. Wright	G. W. Lewis



Clark B. Millikan
IAS Past President, 1937
Director, Guggenheim Aeronautical Laboratory
California Institute of Technology

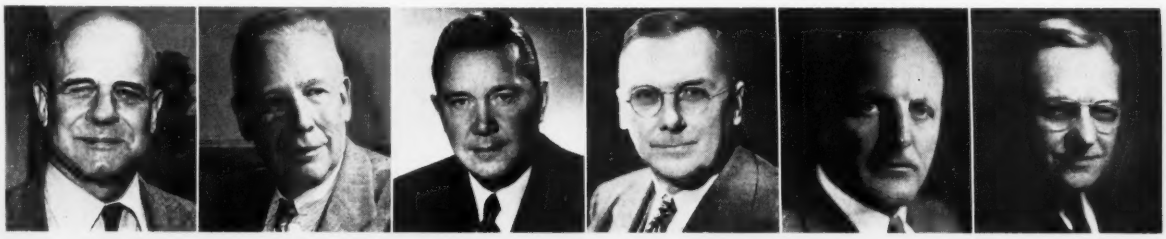
corresponding documents of analogous scientific societies. Plans and arrangements were made for a Founders' Meeting at Columbia University in New York on January 26, 1933.

This meeting, which was attended by some 140 of the new members, started with a technical session of presented papers which I shall discuss further a little later. At the business meeting immediately following, it was reported that the total dues-paying membership had already attained the number of 408 (see Editorial insert, this issue) and that the net assets stood at some $1,500. In the euphoric atmosphere engendered by these figures the membership approved the Constitution and By-Laws, re-elected the Council as already constituted on a temporary basis, and recessed to permit the Council to re-elect the previously temporary officers. Thus at the Institute's very inception were firmly established the traditions of a large and representative technical membership, of brief and smooth-running annual business meetings, and of financial solvency, which have ever since characterized our operations.

For at least the first 10 years of the Institute's life, the annual January meetings were held at Columbia University. They included rapidly growing technical sessions, the business meeting, and an annual dinner which, in the early years, was called a Smoker. This later developed into the glittering, enormous, and formal Honors Night Dinner but was originally a relaxed and highly informal affair. Those who participated with some regularity in the Columbia gatherings will always have nostalgic memories of them: the long subway ride out to the University with the high probability, for non-New Yorkers, of finding oneself far in the Bronx and on the wrong train; the frigid walks to and from the Physics building across the snowy campus; the academic atmosphere of the lecture halls in which the papers were presented; the inimitable and oft-told tale by Charlie Lawrance of the exploits of Monsieur Picon; and the magnificent demonstrations which

industry, have contributed immeasurably to IAS progress."

1940	1941	1942	1943	1944	1945
J. H. Doolittle	F. W. Caldwell	H. L. Hibbard	H. L. Dryden	R. H. Fleet	C. H. Colvin



Luis de Florez' fertile mind concocted for the Smokers and which he presented with the able assistance of such fellow conspirators as Casey Jones and Ed Aldrin. Two of these will never be forgotten by those privileged to witness them. One, a true electronic invention, was called a "Compound, Regenerative Air Regulations Disintegrator and Decoder" and was a most fabulous Rube Goldberg device. The other, a triumph of conceptual creation, was a simple symbol filling a need which every engineer had, at least subconsciously, felt and which had never before been satisfied. It was described by its inventor as being designed "for use by engineers when they reach a point in a formula where they wish to insert a sound resembling a Bronx cheer." Its shape was illustrated by a chart which showed the symbol to be essentially the second letter of the Greek alphabet with numerous convolutions added; the name of "Multi-Bellied Beta" was assigned to it, and the sound it represented was graphically illustrated by the inventor's blowing through a wooden tube with a short thin-walled rubber tube attached to its end. A fair approximation can be achieved with only the tongue and lips after a certain amount of practice.

So much for the reminiscences. In reviewing the Institute's accomplishments and developments since these simple and unsophisticated beginnings, time permits only a brief mention of some of the outstanding features. The membership has grown from the original 408 persons to over 12,000 graded members and 3,000 student members. The latter provides the Society's analog of a most substantial industry backlog. Student Branches have been established at every academic institution offering aeronautical engineering courses, and the Institute expends much effort to ensure that they are kept active and up to date. The half-million dollar Minta Martin Aeronautical Student Fund given to the Institute by the late Glenn L. Martin has made it possible to organize Regional Student Conferences throughout the country (eight were held this spring) at which student papers are presented and judged for awards. The local winners are again judged, and national prizes are awarded for the most outstanding.

The original 1-day Annual Meeting has developed into 2-, 3-, or 4-day sessions, one in New York and the other here in Los Angeles. Over 2,500 persons attended last January's New York meeting where some 90 technical papers were delivered at 26 separate sessions. At the banquets associated with these two Annual Meetings are presented the six major awards of which the Institute has become custodian. These recognize and honor outstanding individual accomplishments in a variety of aeronautical fields. In addition to these two general meetings many shorter meetings, conferences, and symposia are held throughout the country. Certain of these are classified and require security clearance as do many of the visits which the Institute sponsors to military and naval test centers, research establishments, aircraft carriers, and other facilities of technical interest.

As mentioned earlier, the IAS owed much to the Royal Aeronautical Society in its initial organization. The relations between the two societies have become increasingly close over the past 10 years, through the biennial Anglo-American Conferences, the sixth of which will convene in England this September. Similar intimate relations obtain with the recently formed Canadian Aeronautical Institute.

On the broader international scene the IAS has participated actively in the numerous functions of the NATO organization AGARD, the Advisory Group for Aeronautical Research and Development. Beginning this year the Institute is playing a leading role in the establishment of a series of International Congresses in the Aeronautical Sciences, with financial support from the Daniel and Florence Guggenheim Fund. These conferences are to be held during years alternate to the Anglo-American Conferences, and it is hoped that all nations having aeronautical interests will participate, regardless of military or political complexion.

The Institute's physical facilities have had a spectacular growth from the original headquarters office in Lester Gardner's home. The first move was to a small office in the then new RCA building. This continued to expand until finally our own building at 2 East 64th Street was purchased in 1945 with the financial assistance of the aircraft industry. This now serves as the national headquarters in which work the great majority of the Institute's staff of some 80 persons. The growing importance of West Coast aeronautical activities during World War II resulted in the establishment of a Western Regional Office with headquarters in the modern and commodious building which was erected in Los Angeles in 1948. It, and the somewhat smaller San Diego building constructed the following

1946	1947	1948	1949	1950	1951
A. E. Raymond	P. R. Bassett	J. K. Northrop	W. A. M. Burden	J. Kindelberger	L. B. Richardson

year, were made possible by local contributions. These three IAS buildings house the New York libraries and Aeronautical Museum, the Pacific Aeronautical Library, and the Aircraft Technical Film Indexing Project, respectively, and give the Institute library and technical document facilities unequaled by those of any comparable society.

The above examples of the Institute's activities and facilities give some impression of the scope and breadth of its participation in the aeronautical life of the country and the world. It is my own feeling, however, that its greatest contribution lies in the scientific and technical advances which it stimulates by its technical meetings and disseminates through its publications, primarily the original JOURNAL OF THE AERONAUTICAL SCIENCES and its more recent (1941), more engineering slanted AERONAUTICAL ENGINEERING REVIEW.

The first such contribution, combining the two aspects of presentation and discussion of technical material at a meeting and of publication, is contained in the *Proceedings of the Founders Meeting* already referred to. Five short papers and one longer one are included in this thin little volume published in 1933. Dr. James Kimball discussed weather over the North Atlantic which at that time had been traversed nonstop by 20 airplanes and was just on the threshold of becoming an air route. Jimmie Doolittle described an extraordinary series of flight experiences during a program to improve the stability of the Laird 1932 Racer so that an ordinary mortal could cope with it. George Lewis gave an extensive survey of recent aeronautical research and presented the first of what developed into an extensive series of reports on the magnificent experimental facilities of the NACA. Ed Warner made a plea for more use of science and less reliance on empiricism and "horse-sense" in airplane design. A quotation from the written account of his paper reads: "It would be a good thing for every engineering staff to have at least one member whose sole duty it would be to keep abreast of advances in the underlying sciences, in aerodynamic theory, and in the theory of structures, and to press their practical applications constantly upon the attention of his superiors on the staff." It would seem that his advice has been more than heeded in the 25 years since it was given! Professor Auguste Piccard discussed the nature of the stratosphere and predicted that eventually it might be possible for airplanes flying at an altitude of some 50,000 ft. to attain a maximum speed of 450 m.p.h. Professor C. F. Taylor in discussing power-plant development pleaded for the adoption of forged cylinder heads, reduction gearing for propeller drives, and fuel injection.

The following year saw the birth of the Institute's famous JOURNAL whose first issue appeared in January, 1934, and which has continued ever since as the leading periodical covering the scientific aspects of the country's aeronautical life. A review of the papers which have appeared in it over the past 25 years, carried out by Karl Bergey of the Los Angeles Section, has revealed the extraordinary breadth and significance of the contributions to aeronautical science which the JOURNAL has presented. Even a listing of the outstanding examples would require far more space than is available here. Accordingly I have selected just a few samples which appeared during the early years so that a comparison might be made between the subjects receiving most attention 20 to 25 years ago and those which are of greatest interest today.

The first paper in the initial issue was von Kármán's classical review, "Turbulence and Skin Friction." During the next few years fundamental contributions to this general field were reported by Dryden, G. I. Taylor, B. M. Jones, von Kármán himself, and others. Also in the initial issue was Stack's first paper on "The Effects of Compressibility on High Speed Flight." This was followed over the next decade or so by many theoretical and experimental discussions of compressibility effects, both for inviscid and for boundary-layer flows, by such authors as Stack himself, von Kármán, Tsien, Liepmann, Laitone, and many more. During the mid-1940's supersonic wing theory received much attention, starting with Puckett's delta-wing paper in 1946.

In the field of structures, problems associated with semimonocoque design and the behavior of stiffened thin sheets were treated by Hoff, Southwell, Reissner, and others. Many important papers appeared on various aspects of buckling phenomena. Rauscher's 1936 paper on flutter was the first of many devoted to the structural and aerodynamic aspects of this important field.

Also in 1936, Draper's first papers on instrumentation and vibration measurements in flight appeared,

(*Continued on page 39*)

1952
W. E. Beall

1953
C. J. McCarthy

1954
J. L. Atwood

1955
R. E. Gross

1956
E. R. Sharp

1957
M. I. Peale

"...THE TIME IS BOUND TO COME WHEN
MAN WILL VENTURE EVER DEEPER INTO SPACE—
NOT TO WIN WARS ON EARTH
BUT TO BATTLE THE LIMITLESS CHALLENGE OF THE UNIVERSE."

AIR FORCE RESEARCH AND DEVELOPMENT IN

There are several compelling reasons for the Air Force's interest in space technology, the most important one being the fact that, for all practical purposes, we are already operating in space or, more accurately, under conditions approaching those of space. Ninety-nine per cent of the atmosphere lies below 20 miles. This altitude has already been exceeded by manned aircraft. Last year, Capt. Iven Kincheloe of ARDC's Air Force Flight Test Center flew the Bell X-2 rocket-powered test vehicle to an altitude which I can now confirm to have reached 126,200 ft. As you will remember, he was recently awarded the Mackay Trophy for this achievement.

While Captain Kincheloe flew higher than any man had ever flown before, it would not be correct to say that he had reached "space," although there is no recognized borderline beyond which altitude above, or distance from, the surface of the earth should be considered "space." But even an altitude of 20 miles—a little over 100,000 ft.—represents an extension of only one half per cent beyond the earth's radius. In comparison, this would be equivalent to a distance of about one hundredth of an inch from the surface of a regulation baseball.

On the other hand, many of the complex problems associated with operations in space begin to be more and more evident at altitudes beyond 100,000 ft., mainly because of the extremely low density of the atmosphere. The use of air-breathing engines and aerodynamic control surfaces becomes increasingly difficult and eventually impossible. Above 50,000 ft., "altitude" actually begins to be "space" as far as human survival in nonpressurized environments is concerned. Altitudes beyond 130,000 ft. are equivalent to space with respect to heavy, primary cosmic ray particles.

Above 20 miles the atmosphere is too thin to reduce various types of solar radiation to below a lethal level. Meteoric particles and dust become distinct hazards. And with increasing distance from the earth's surface, the little-known problems of decreasing weight must be taken into account.

The altitudes explored by the X-2 and to be explored by advanced research vehicles such as the X-15 can be expected to become the operating altitudes of combat aircraft in the not too distant future since the primary purpose of research airplanes is to pace the performance of operational military aircraft which, in turn, pace that of commercial airplanes. Because the environmental problems encountered at the altitudes already attained are, in many respects, equivalent to those of space, their thorough investigation *today* is a prime prerequisite of flight at the operational altitudes of *tomorrow*.

This applies to an even greater degree to unmanned aerial vehicles, especially long-range ballistic missiles, although the scope of the space problem is narrowed by the absence of the human factor. Several missiles are already being tested at altitudes at which it is mandatory to consider the effects of powerful solar radiations, collisions with meteoric debris, and the impact of extreme environmental conditions on the operation of delicate guidance and control instruments. Another most difficult problem posed by missile flight in near space results when the missile's nose-cone, which contains the pay load of instruments or warhead, re-enters the atmosphere at speeds and temperatures far beyond those with which human ingenuity has ever had to cope.

But current Air Force projects in the field of space technology cannot be limited to the solution of problems encountered in the development of high-altitude aerial vehicles—both manned and unmanned. All strategic and tactical planning is predicated on an estimate of the situation gained from all aspects of

This speech was presented at the June 19 banquet, IAS National Summer Meeting, Los Angeles, Calif., June 17–20, 1957.

At the time of this presentation, General Power was Commander, Air Research and Development Command, USAF.

Space Technology

Lt. Gen. Thomas S. Power, USAF

Commander-in-Chief, Strategic Air Command

intelligence. Not the least of these is an intimate knowledge of the terrain or, in the modern three-dimensional war, the atmosphere.

It is just as important for the Air Force to have the fullest possible intelligence of the atmospheric and space theaters of operations as it is for the infantry to know the earth. For in the aerial dimension of warfare, the old mandate to "take to the high ground" is as vital to the Air Force as it ever was to the rifle-bearing soldier. It therefore stands to reason that every aspect of space must be explored in order to obtain all the intelligence essential for dominance of what some day may well become the principal theater of operations.

Because of my new assignment, these considerations are now of particular concern to me. It is not always understood that superior strategic capability entails much more than just superiority in strategic materiel. It would be misleading to compare our strategic capability and that of the Soviets merely by comparing our strategic bombers and missiles with their Soviet equivalents. This would be just as unrealistic as trying to determine the chances of the participants in a photographic contest merely by comparing the quality of their cameras!

Strategic capability is the sum of many factors which, in addition to the strategic weapon itself, include the entire weapon *system*, the organization available to employ that weapon system, the special training and maintenance facilities, and adequate logistic system, weather service, target intelligence, and the worldwide communications network required to tie all these components together. The quality of the overall strategic system depends on the quality of each individual component. To have superior strategic capability, the quality of all components must be superior to that of any potential enemy.

It is my considered opinion that our Strategic Air Command represents a strategic capability which, in every respect, is superior to that of the Soviets. But indications are that the Soviets are making an all-out effort to surpass us. To protect and, if at all possible, widen our present lead we must therefore continue an aggressive research and development program in reaching successively higher plateaus of scientific advancement in all areas of military technology.

This means that, in order to maintain our superior strategic capability, we must continue to advance the state-of-the-art in every one of the many fields which, directly or indirectly, contribute to the effectiveness of long-range, strategic operations. Among these fields, space technology is one of the most far-reaching because many of the phenomena occurring in space have a profound bearing upon communications, control, navigation, and air weapon operations conducted at much lower levels.

Better knowledge of the basic effects of solar radiation on the atmosphere will lead to a better understanding of the movements of polar air masses and the jet

stream and will thereby permit improved weather forecasting and flight planning. Better knowledge of the nature of the ionosphere, cosmic rays, and meteoric debris will lead to better radio communications and more reliable navigation methods. As we gain advances in these and other fields of space technology, we pave the way for continued advances in our strategic capability.

These then are the factors which determine the scope of the Air Force's research and development effort in space technology. And now I should like to tell you briefly about a few representative projects which contribute to that effort. Time and security limitations do not permit me to discuss these projects in detail. However, I hope that they will indicate the potential for quantum advances that better knowledge of space phenomena will create.

Solar radiation is the predominant cause of the physical and chemical events in the atmosphere, yet the effects of the sun on the atmosphere are still relatively unknown. To broaden this limited knowledge, the Air Force Office of Scientific Research and the Cambridge Research Center have entered into a number of study contracts with various universities. Sun spots and huge flares shooting out from the sun are being closely studied at ARDC's Upper Air Observatory on Sacramento Peak, New Mexico, to determine the effect of solar disturbances on the atmosphere and radio communications.

The nature and variations of cosmic radiation are being studied for the Air Force at the Universities of Chicago and Maryland. Cosmic ray alarm systems may permit the prediction of magnetic storms on the sun and thereby warn of impending radio disturbances.

One of the most important areas of space technology to the Air Force is the effect of space phenomena on communications. It has been said that communications represent the nervous system of modern warfare. This is especially true of global, strategic operations which require instantaneous and reliable communications to link elements thousands of miles apart effectively.

Many of our long-range communication problems stem from the ionosphere, a region ranging from about 50 to 250 miles above the earth's surface, where particles are "ionized" or charged electrically. Thorough investigation of this region not only is necessary in meeting the problems it poses but also has shown that some of its unique properties can be used to advantage, such as in bouncing radio signals off meteor trails. About 60 miles above the earth, meteors create trails of ionized air which reflect very high frequency radio waves and thus permit great extension of the range of this type of communication, normally limited to the line of sight.

Much work is being done in improving the techniques of weather observation and forecasting so vital to Air Force operations. Better knowledge of the effect of space phenomena on terrestrial weather; increasing automation of weather data collection and transmission; and subsequent improvement in the objectivity, accuracy, and speed of data interpretation through the use of computers will all contribute to greater efficiency in weather prediction.

The Air Force is also very much concerned with investigations of the gravitational forces exerted by the earth, as well as by bodies in space, and with studies on terrestrial magnetism. Since missiles and manned aircraft will fly through both of these environments, we must be able to predict their effects at altitude to permit the preparation of accurate maps and charts. As part of this program, the Air Force Cambridge Research Center recently conducted an air-borne observation to determine the exact location of the earth's geomagnetic equator.

Space technology further entails the study of the meteor problem which affects all vehicles flying at altitudes above those sufficiently dense to burn up meteoric particles streaking toward the earth. Detailed information on the number and mass of meteorites is important not only for the design of missiles and vehicles exposed to them but also because of their effect on the ionosphere and radio communications.

A great deal of research has been and is still being directed toward the development of improved or radically new propulsion systems for operation beyond the atmosphere. In addition to extensive work for the improvement of rocket engines using liquid and solid propellants, which power many of our current missiles, other methods of propulsion are under investigation, such as means for using the energy liberated in various chemical processes or the possible use of solar energy as a primary propulsion source. Another approach in the initial study stage is based on the theory of ion propulsion which envisions the reaction from the discharge of ions—electrically charged atoms—as a means of providing a small but steady thrust.

Operation under space conditions also poses manifold problems for the equipment designer. One problem area concerns the provision of lightweight, self-contained secondary power sources for instruments and other components. Among several studies in this field are projects at the Wright Air Development Center to develop efficient nuclear batteries and practical means for converting solar into electrical energy.

One of the most interesting and extensive areas in space technology is that of human factors. There is, for instance, the problem of reduced weight or complete weightlessness. While weightlessness occurs in certain high-speed aerial maneuvers for short periods, relatively little is known of its physical and mental effects over extended periods of time. Current investigations are expected to shed more light on this matter. Related projects deal with the stress and fatigue associated with flights of extremely long duration.

The effects of high gravitational forces are studied by volunteers on human centrifuges and rocket sleds. Other volunteers test means for existence under near-

vacuum conditions in high-altitude chambers which can simulate altitudes up to 200,000 ft. Investigations of the biological effects of cosmic radiation at Holloman Air Development Center included tests with animals carried aloft by high-altitude balloons for as long as 35 hours.

While these and many other related projects are not intended to solve the human problems of space flight, their results will undoubtedly prove of value if and when man is ready to proceed from space-equivalent altitudes into space itself. Similar considerations apply to most of our current projects in the development of high-speed, high-altitude aircraft and long-range missiles.

But our primary concern for today and tomorrow must be the investigation and mastering of those environments which, although in many respects equivalent to space, represent realistic estimates of the altitudes to which military operations may be extended in the foreseeable future.

If our efforts in military technology continue to maintain for us a truly deterrent force, the time is bound to come when man will venture ever deeper into space—challenge of the universe.

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First Quarter Century *(Continued from page 35)*

and these were followed by numerous contributions to instrumentation development. Transport aircraft design and operation were treated by Donald Douglas, W. B. Oswald, T. P. Wright, and others, as early as 1935. During the early years power-plant papers were primarily concerned with reciprocating engines and propellers, although in the mid-1940's gas turbines and other types of jet propulsion began to appear as subjects.

These few examples will perhaps serve to recall the kinds of topics which were of primary interest 20 or more years ago. Since that time the JOURNAL, like the Institute itself, has grown tremendously in size and continues to reflect the problems which aeronautical scientists and engineers find most challenging. A glance at the papers which have appeared in the last year or two indicates that the turbulence and skin friction problems are still very much with us, although a new aspect—heat transfer at high supersonic and hypersonic speeds—has appeared. The aerodynamics of extremely thin bodies for high supersonic speeds, and especially wing-body interference effects, are much in evidence, and explorations of the true hypersonic regime are numerous. The greatest interest in the structural field is in the effects of high temperatures and in aeroelasticity, especially panel flutter, both of which are associated with flight at extremely high speeds. In aircraft design much attention is devoted to helicopters and other types having short or vertical take-off and landing characteristics. Papers dealing with power plants are now almost entirely concerned with gas turbines and their components. An entirely new field has emerged and is the subject of much attention. This concerns the noise produced either by jet engines or by boundary layers flowing over smooth surfaces at high supersonic speeds.

Clearly, our JOURNAL, like all the other facets of the Institute, satisfied a real need in the aeronautical world when it was created and has continued to grow and develop during its first quarter century so as to play an ever-increasing role in our professional life. With the capable and dedicated staff which so effectively manages all of our complex activities, it is certain that the next 25 years of the Institute of the Aeronautical Sciences will be even more valuable and rewarding than the first.

A Special Report on the

IAS NATIONAL SUMMER MEETING

Summary of Technical Sessions

Allan Bernhardt

Over 1,300 registrants for the technical sessions at Los Angeles in June set another high for attendance at IAS national summer meetings.

Simultaneous sessions at the Biltmore and the Institute Building provided a more varied program than has ever been presented at these summer meetings. With twelve sessions at the hotel, two classified meetings at the IAS Building, and a classified field trip to Palmdale, the 4-day conference covered a wide variety of timely subjects. The officers and committees of the Los Angeles Section deserve many plaudits for pulling this one together and running the show.

Mr. Bernhardt is Assistant Editor of the *Review*.

Of the 14 technical sessions (as against nine at the 1956 National Summer Meeting), four took the form of panel discussions. They covered Aviation History, Business Aircraft, The Engineer in Management, and Systems Concept.

A total of 32 technical papers, five of which were classified, were heard this year. Last year, the total was 26, nine classified.

IAS President Mundy I. Peale presided over the dinner in the Biltmore Bowl which more than 900 persons attended. Lieutenant Gen. Thomas S. Power delivered the principal address. This and the luncheon talk by Dr. Clark B. Millikan may be found on pp. 36 and 32, respectively, in this issue.

The National Summer Meeting Banquet was held at the Biltmore Bowl, Los Angeles, on June 19.

While many of the papers presented at this meeting will be published in the REVIEW and JOURNAL, a limited number of preprints of some of them are still available. (See page 115.) A summary of the 27 nonclassified papers presented follows, with sessions listed alphabetically:

Aerodynamics

***Chairman*, Charles Wood, Chief Engineer, Long Beach Div., Douglas Aircraft Co., Inc.**

***Coordinator*, Stanford Church, Douglas Aircraft Co., Inc.**

Three papers encompassed subjects in this field. A presentation by William T. Hamilton, Staff Engineer, Aerodynamics, Boeing Airplane Co., discussed "Design Considerations in Use of Powered Augmented Lift Systems" and made a comparison of take-off performance characteristics for a transport aircraft utilizing mechanical flaps, boundary-layer control flaps, or jet flaps.

"The Research Airplane—Past, Present, and Future" was the subject of a paper by Walter C. Williams and Hubert M. Drake, of the High-Speed Flight Station, NACA, Edwards, Calif. Work with ten specific aircraft was discussed, as were present supersonic flight research investigations and the future role of the research airplane in the exploration of problem areas in the hypersonic flight regime.

A paper by W. R. Sears, Director, and E. L. Resler, Jr., Associate Professor, Graduate School of Aeronautical Engineering, Cornell University, debated "The Prospects for Magneto Aerodynamics." The authors suggested that electrical methods appear to be essential for flight outside the earth's atmosphere where matter is scarce.

Aviation History

***Chairman*, Gen. Ira Eaker, USAF (Ret.), Vice-President, Aircraft Div., Hughes Tool Co.**

***Coordinator*, R. C. Whitaker, Marquardt Aircraft Co.**

This panel discussion, interpreting lessons of the past for illumination of the future, featured talks by three of aviation's most illustrious leaders. Speakers were Donald W. Douglas, President, Douglas Aircraft Co., Inc.; J. H. Kindelberger, Chairman of the Board, North American Aviation, Inc.; and Robert E. Gross, Chairman of the Board and Chief Executive Officer, Lockheed Aircraft Corp.

Major Gen, Project Officer of AF Plant 42 at Palmdale, briefs IAS members on flying activities during classified field trip to Palmdale, June 20.

Business Aircraft*

***Chairman*, William P. Lear, Sr., Chairman of the Board, Lear, Inc.**

***Coordinator*, Ben Cagle, Southern California Cooperative Wind Tunnel, C.I.T.**

The USAF's interest in the great number of airplanes included in the Business Aircraft category was outlined in the first paper of this discussion Major Gen. J. W. Sessums, Jr., Vice-Comdr., ARDC, USAF, explored "Executive Aircraft for Business and Military." Releasable engine data also were presented.

The availability of power plants, their adaptability to present and future aircraft, and the economics of developing and marketing the latest engineering concepts in business aircraft were taken up in the paper, "Engineering Approach to Business Aircraft." The author was Ralph M. Harmon, Chief Engineer, Business Transport Aircraft, Cessna Aircraft Co.

The audience at this discussion heard August Raspet, Head, Aerophysics Department, Mississippi State College, deliver a paper on "Contribution of New Concepts in Aerodynamics to Executive Aircraft." It placed business aircraft in three categories and forecast that the utility of each will be increased if they are given better cruising efficiency, take-off and landing performance, and new control methods for safer flight.

"Business Aircraft—Yesterday, Today, and Tomorrow" was the topic of G. Edward Rice, NBAA Representative, Manager of Commercial JATO Sales, Aerojet-General Corp., Division of General Tire and Rubber Co. Mr. Rice presented an analysis of the existing market for business aircraft and business aircraft equipment.

Some of the major aspects that an air-frame manufacturer must consider in the development of a new model, and of a high-speed business transport in particular, were debated in the paper, "Prop-Jet and Turbojet Business Aircraft," by Winfield Arata, Jr., Chief Operations Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corp.

The paper by John T. Calhoun, Chief Design Engineer, Beech Aircraft Corp., pointed up a need for a significant increase in speed capabilities for the business fleet at reasonable airplane-mile and initial equipment costs. His subject was "The Role of the MS 760 in the Business Fleet."

* Papers were presented by all six speakers in this panel discussion. A special condensation in the November REVIEW will interpret more fully the thoughts of each speaker on his subject.

Control Systems

***Chairman*, Allen E. Puckett, Director of Operations, Systems Development Lab., Hughes Aircraft Co.**

***Coordinator*, J. F. Aldrich, Douglas Aircraft Co., Inc.**

Three papers made up this technical session. Oliver E. Deal, of Hughes Aircraft Co., discussed "A Reappraisal of Pilots' Situational Displays" and considered various categories of displays. Research methods were analyzed from the pilot's viewpoint. Effects of displays on pilot accuracy and flight safety were discussed on the basis of flight experience.

An analysis of the relative merits of various possible electrical control systems was presented in the paper, "Analysis of an Electrical Flight-Control System for Interceptor-Type Aircraft."* The authors were E. Price and R. Westerwick, Senior Dynamics Engineers, Convair, A Division of General Dynamics Corp.

A paper on "The Effects of Vortex and Shock-Expansion Fields on Pitch and Yaw Instabilities of Supersonic Airplanes" was presented by Jack N. Nielsen and George E. Kaattari, Aeronautical Research Scientists, Ames Aeronautical Laboratory, NACA. General design principles to avoid pitch-up and yaw instability were discussed.

Development of the F-104

***Chairman*, E. G. Stout, Manager, Nuclear Development, The Ralph M. Parsons Co.**

***Coordinator*, C. R. Cantrell, Lockheed Aircraft Corp.**

This session was classified.

Electronics in Aviation

***Chairman*, Ralph F. Redemski, Vice-President, Research, Servomechanisms, Inc.**

***Coordinator*, R. G. Klammer, Hughes Aircraft Co.**

This session was led off by the paper, "Some Fundamental Principles of Collision Warning," by Emory Lakatos, Member of the Technical Staff, Control Systems Division, The Ramo-Wooldridge Corp. Mr. Lakatos' presentation was divided into two parts. The first dealt with the general philosophy of the problem. The second dealt with some of the principal operating problems.

Victor Azgapetian, Chief Systems Engineer, Servomechanisms, Inc. (Eastern Branch), reported in a paper on "System Considerations in Instrument Dynamics" that present-day instrumentation for aircraft is such that the dynamic errors of ordinary altitude, Mach Number, and angle of attack systems are not a function of the dynamic characteristics of the instruments proper. The actual dynamic effects, especially in the case of angle of attack and Mach Number, do not come from the application of simple dynamic lags to the variation of the true value, he said, listing possible im-

* This paper was published in the August issue of the REVIEW, pp. 63–67, 77.

provements that can be effected by certain methods of system design.

Electronic subsystems as contributing factors in a successful mission by a bomber aircraft were described in the paper by R. L. Shahan, Boeing Airplane Co., Seattle Division, entitled "The Role of Electronics in the Strategic Bomber." An example was given of a contractor's experience with a complex new bombing navigation system, and the laboratory evaluation program was described together with plans for a comprehensive flight-test program.

The Engineer in Management

***Chairman*, J. L. Atwood, President, North American Aviation, Inc.**

***Coordinator*, Stanford Church, Douglas Aircraft Co., Inc.**

Five members of this panel discussion covered an equal number of subjects. These were presented in question form, designed to be of especial interest to the practicing engineer. Panel members answered questions from the floor after their quarter-hour talks. Subjects discussed and the observations of each member, considerably abridged, follow:

(1) "What is the Manager's Function?" by L. A. Hyland, Vice-President and General Manager, Hughes Aircraft Co.

There are four he must perform. Primarily, he must make a profit; this is how an organization's success is measured.

He must maintain a balance within the organization. Its functions must complement each other properly.

He must keep all personnel informed to guard against surprises; this will facilitate fast action with sureness and conviction.

He must train and indoctrinate the organization as a whole to the end that competence which might be graded as marginal can produce superior performance.

(2) "To What Extent Does an Engineer's Training Prepare Him for Management?" by G. S. Trimble, Jr., Vice-President—Engineering, The Martin Co.

An engineer's training provides him with (a) the ability to define and solve problems, (b) the ability to organize his thinking in a logical and orderly process, (c) an ability to treat a situation with intellectual honesty, and (d) the desire to find the *correct* answer.

All these skills apply to management problems. But the management philosophy requires that an engineer—once in management—realize that he may not find a perfect answer to a problem as in a mathematical calculation. Perfection is elusive; one may find only 30 per cent agreement among managers in a typical management problem.

(3) "What Should Be the Engineer's Choice—Technical Specialization or Management? What Factors Influence His Decision?" by Leo A. Carter, Vice-President and General Manager, Santa Monica Division, Douglas Aircraft Co., Inc.

An engineer should evaluate his potential from the standpoint of what he wants to do. Testing services may help. But if he finds himself in the wrong niche, he should take corrective action. If he is debating a management career, he should weigh the following:

A manager must deal with people and, because he cannot do everything himself, must have confidence in them. He cannot be narrow-gaged and must want to learn about marketing, economics, manufacturing—all related items that make up the final product. He must recognize and use qualified specialists.

(4) "What Should an Engineer Do to Improve His Management Skills and Knowledge?" by Dimitrius Gerdan, Director—Engineering, Allison Division, General Motors Corp.

Characteristics he should develop are an awareness of customer needs and requirements; an interest in company activities and his organization's part in the whole; an interest in the company's products beyond his part; the ability to speak and write well; the ability to make decisions (make practice decisions, then compare and assess his with ones actually made); an awareness of people, their behavior, and motivations; a willingness to work harder as he progresses. A good manager thrives on more work.

(5) "What Should Industrial Management Do to Help an Engineer Improve His Management Skill?" by Myles L. Mace, Vice-President, Litton Industries, Inc.

Outside aids in the form of various courses are available, but inside on-the-job training is more practical and useful. Job progression and rotation is a technique that should be used more. There should be a plan to develop qualities which management wants to see in a person for a future job. Coaching of an employee by his supervisor is effective. He must help the subordinate learn by delegation of responsibility and authority—stretching the subordinate's capacity by permitting him to assume responsibilities in new areas, counseling (must be done with sincerity, not superiority), creation of a desire for team spirit, encouraging participation, keeping him informed of responsibilities and how his performance will be measured, establishing mutual confidence, and by giving fair treatment.

Environmental Testing

***Chairman*, W. Vandal, Group Leader, Environmental Lab., Autonetics Div., North American Aviation, Inc.**

***Coordinator*, R. C. Whitaker, Marquardt Aircraft Co.**

The initial paper of this session, "New Sonic Test Environments and Facilities," by K. R. Jackman, Head, Engineering Test Laboratories, Convair, A Division of General Dynamics Corp., reviewed some of the sonic specifications applicable to the high-intensity acoustical testing of missile structures (sonic fatigue) and electronic components (sonic reliability). Also reviewed were some Convair-Pomona efforts to develop high-intensity noise in plane-wave tubes by means of low- and high-pressure air sirens.

The second paper was "Environmental Simulation: A Tool for the Contemporary Engineer." The author, H. John Cail, Department Head, Environmental Facilities Group of the J. B. Gill Division of Paul Hardeman, Inc., traced the history of environmental simulation

with reasons for the inception of the art and its subsequent rapid growth to the status of a specialized branch of engineering. Also, he listed the type of test commonly performed today and described general classes of equipment in use.

"Environmental Testing of Avionic Equipment" by Robert H. Douglass, Jr., Supervisor, Qualification, Environmental and Reliability Group, Servomechanisms, Inc., discussed standard military specifications, the role of the laboratory in the design effort, and various tests and their intent.

Flight Testing

***Chairman*, George R. Mellinger, Manager, Engineering Flight Test, North American Aviation, Inc.**

***Coordinator*, Ben Cagle, Southern California Cooperative Wind Tunnel, C.I.T.**

A set of general specifications for a VTOL fighter-type airplane, with the reminder that great expenditures will be involved if a practical VTOL aircraft is to be produced, was contained in the first paper of this session—"Flight Testing and Development of VTOL Aircraft." The author was Charles E. Myers, Jr., Engineering Test Pilot, Convair, A Division of General Dynamics Corp. The paper includes a list of references which may serve as an aid to those embarking on VTOL development programs.

In a paper on "Flight Testing of Supersonic Aircraft," W. L. Howland, Flight Test Division Engineer, Lockheed Aircraft Corp., discussed the general effect of shrinking of time and the effect of supersonic speeds on the engineering test pilot's job. Also taken up were major problems associated with determining performance, evaluating stability augmentation, methods for studying flutter and flutter margins, effect of new speed regime on measurements, and data processing and analysis.

A discussion of flight-test program planning and scheduling considerations, and some of the problem areas attendant on the satisfactory accomplishment of such programs, was contained in the paper, "Flight Testing of Guided Missiles." The author was Milton Kuska, Chief, Missile Field Test, Northrop Aircraft, Inc.

Facilities for assembling, remotely disassembling, and examining components of the aircraft nuclear power plant were described in the paper, "Testing Aircraft Nuclear Power Plants." The presentation, which dealt with other incidental problems including handling of data, was by Albert R. Crocker, Manager—Test Operations, Aircraft Nuclear Power Project, General Electric Co.

Guidance Systems

***Chairman*, R. M. Ashby, Chief Engineer, Autonetics Div., North American Aviation, Inc.**

***Coordinator*, J. F. Aldrich, Douglas Aircraft Co., Inc.**

The basic functions of all navigation were analyzed in the first paper of this session, "Principles of Self-Contained Navigation,"* by H. H. Bailey, Physical Scientist, Electronics Department, The RAND Corp. Also, the basic principles of inertial navigation were developed.

"Problems in Doppler Navigation," by two representatives of Raytheon Manufacturing Co., dealt primarily with problems associated with Doppler principles as applied to aircraft navigation. Authors were F. T. Wimberly, Manager, Navigation Systems Department, and C. L. Crowell, Section Head, Fighter Navigation Systems Section, Maynard Laboratory.

Star tracking, checkpoint incorporation, velocity damping, and the importance of an accurate coordinate system were outlined in the paper, "Aids to Inertial Navigation." The authors were Frederick Stevens, Chief, Missile Guidance and Controls; and Frank W. Lynch, Assistant Chief, Guidance and Controls, Northrop Aircraft, Inc.

Two members of the Autonetics Division of North American Aviation discussed translational vibration in relation to platform tilt and analyzed the kinematic rectification of platform and gyro motions in the final paper of the session, "Stable Platforms for High-Performance Aircraft." The authors were R. H. Cannon, Research Specialist; and David P. Chandler, Supervisor—Electric Components, Research Group.

Propulsion

***Chairman*, E. J. Specht, Manager, Propulsion Systems Unit, Western District, General Electric Co.**

***Coordinator*, Stanley W. Mikulka, General Electric Co.**

This session was classified.

Structures

***Chairman*, G. N. Mangurian, Chief Analytical Engineer, Northrop Aircraft, Inc.**

***Coordinator*, D. M. Badger, Northrop Aircraft, Inc.**

The first paper of this session, "Thermal Creep Design Criteria," by Robert Goldin, Chief Structural Design Engineer of Bell Aircraft Corp., reviewed the considerations involved in introducing the aspect of creep into practical drawing-check stress analyses.

In order to clarify the physical conditions of various types of panel flutter in transonic and supersonic flows, several exploratory experiments were reviewed in the paper, "On Panel Flutter." The author was Y. C. Fung, Associate Professor of Aeronautics, C.I.T., and Consultant, The Ramo-Wooldridge Corp.

Pointing to some confusion over relative merits of titanium and steel alloys, the paper by Donald D. Cox, Weight Unit Chief, Structures Staff, Boeing Airplane Co., urged that a study to compare material efficiency should be related to a specific design because it is important to know the temperature-load relationship, as well as the temperature-strength relationship. The paper was entitled "The Selection of Structural Materials for Supersonic Flight."

* This paper was published in the August issue of the REVIEW, pp. 68-73.

Systems Concept

***Chairman*, Trevor Gardner, President, Hycon Manufacturing Co.**

***Coordinator*, R. G. Klammer, Hughes Aircraft Co.**

The future management pattern for major weapons systems development projects was taken up at this panel discussion. Dr. Dean E. Wooldridge, President of The Ramo-Wooldridge Corp., acted as moderator when Chairman Gardner found he could not be present. Other speakers were Richard R. Hough, Vice-President, Bell Telephone Laboratories; Major Gen. David Baker, Director, Procurement and Production, Air Material Command; Major Gen. H. M. Estes, Director, Systems Management and Assistant Deputy for Weapon Systems, ARDC, W-P AFB; and August C. Esenwein, Vice-President and Division Manager, Convair, Fort Worth.

Dr. Wooldridge, president of the company that acts as technical director and scientific manager of the huge USAF Ballistic Missiles Program, said that the unique pattern whereby systems engineering and technical direction responsibility were assigned to an industrial contractor had been evolved by the Air Force for that project because of the urgency, size, and complexity of the program. He added that such a combination of circumstances might never again arise to require a similar systems management structure.

Both Dr. Wooldridge and Mr. Hough concurred in the belief that another factor which might limit the future use of systems management contractors could be present procurement policies that permitted a relatively small financial return to purely research and development contractors compared with production contractors. Generals Estes and Baker agreed that this would probably limit the employment of such a management pattern. General Estes, however, expressed the view that in special instances the USAF might need to repeat the basic organizational pattern exemplified by the ballistic missile program because of the inadequacy of other techniques in supplying the necessary technical assistance to the USAF. He stated that an overall national defense system, for example, might some day require just such an approach and application of systems management.

Mr. Hough declared that thorough systems study is necessary at the point where requirements are being set up. This would lead, he said, to establishment of practical criteria within the state of the art as it would exist at the time the weapons systems became operational. Stating the belief that design competitions as presently set up and required were wasteful of time and money, Mr. Hough added that under his procurement concept weapons systems designs of individual bidders could not incorporate all advanced and desirable features owing to the restricted dissemination among contractors of development information.

General Estes observed that the present system of proposals and selection is the only possible way for the Air Force to obtain the best product. Any other method, he said, would greatly delay the decision-making process by necessitating vast data analysis.

In a discussion of the use of engineers in weapons systems research and development, Mr. Esenwein said that Convair had employed 2,000 engineers in development of the B-58. Of this number, 40 were engaged in subcontractor monitoring for overall progress but were not used to give special technical direction of subcontractor activities.

Mr. Esenwein and Dr. Wooldridge emphasized that there is no substitute for the use of technical men to direct and administer technical activities and that such a use of selected scientists and engineers is one of the best ways to enhance the overall effectiveness of large professional groups.

Technical Requirements Planning

***Chairman*, Carlos Wood, Chief Engineer, Long Beach Div., Douglas Aircraft Co., Inc.**

***Coordinator*, Stanford Church, Douglas Aircraft Co., Inc.**

The importance of sound early planning and programming was stressed in the first paper of this session, "Around the Requirement in Thirty Minutes," by Rear Adm. D. J. Welsh, USN, Assistant Chief for Plans and Programs, Bureau of Aeronautics, Navy Department. Admiral Welsh defined the requirement as the key to who, what, when, and how much industry may be involved in a program.

Air Force research and planning documents and their role in providing guidance were discussed in the paper, "Research and Development Planning in the U.S. Air Force," by Lt. Col. C. R. Tosti, USAF, Assistant Executive Officer to the Commander, ARDC, Department of the Air Force.

Raymond D. Kelly, Superintendent of Technical Development, United Air Lines, Inc., debated what must go into contemplation of an order for a fleet of aircraft, reciting one specific study by United. His paper was entitled, "Air-Line Technical Requirements Planning."

The recommendation that industry assist greatly in long-range weapon systems planning was made in the paper, "The Role of Industry in Weapons System Planning." The authors, Sherwood C. Frey, and P. R. Carlson, Military Operations Research Division, California Division, Lockheed Aircraft Corp., declared it is appropriate that industry should provide bases for decision, coordinating with Government policy and with the military while so doing.

▲ ▲ ▲

Laboratory and flight-test programs involving structures at elevated temperature are reviewed. It is concluded that design methods suitable for elevated temperatures to 1,200°F. are currently feasible.

Thermoelastic Distortion and Wing Structural Design

John H. Meyer
McDonnell Aircraft Corporation

Introduction

A great deal of attention is centered on the "thermal thicket" with the advent of power plants that can drive properly designed airplanes deep into this thicket. Numerous phases of the problem have been thoroughly explored analytically.

Little has been written about the "nuts and bolts" aspects of thermostructural design. It is generally understood that the thermal problem up to Mach Numbers of 3 to 6 can be handled with available materials (machinery in steam boilers, engines, etc., has been operating close to the material limits for years), but it presents a difficult design problem because so many variables need to be considered in determining the lightest structure with adequate characteristics. Further, the penalty for selecting a nonoptimum structure is large: the weight penalty invested in the "wrong" design can cause a specific airplane to be completely outclassed in performance.

This paper examines various methods of detail structural design and attempts to bring out their limitations and possibilities.

Operating Conditions Posing Design Problems

High Mach Number flight imposes temperatures of about $(1 + 0.2\ M^2)$ degrees absolute times ambient temperature. References 1 and 2 go into detail on temperature magnitudes in relation to particular mission profiles.

These external skin temperatures flow into the structure, creating stresses, strains, and wing deformations of various types and magnitudes. Reference 3 discusses various effects in this field.

The problem of getting an airplane to behave properly without any thermo-elastic-mechanical disturbances is no easy one. The recent engrossment of aeronautical designers with lateral control, roll-yaw coupling, and pitch-up, to mention a few of the more spectacular troubles, attests to the difficulty. Equally difficult problems of more prosaic nature are ever-recurring. Since almost all of an aircraft's bad habits which involve structural characteristics can be cured by adding more or heavier material, it appears that the best performing airplane is likely to be one which is on the thin edge of every aeroelastic problem in the book.

The advent of the thermal thicket simply superimposes thermo-elastic-mechanical problems on all the present problems, introducing the new variables of plasticity and time in addition to the previous considerations of elasticity.

Review of Experience on Thermal Structures

Various studies have been made, laboratory and flight tests conducted, and airplane components designed and built at McDonnell, some of which involve temperatures up to 1,200°F. or thereabouts. Some of this work is reviewed herewith.

Engine temperatures have been of greatest immediate concern. Fig. 1 shows temperatures measured in flight on the aft fuselage of the F-101A. Methods of construction were developed over a period of several years which perform adequately in this environment, which is characterized not only by extreme temperature gradients but by sonic fatigue imposed by the presence of the J-57 engine blast. The combination has led to the use of the insulation and shingle construction indicated in Fig. 2.

The general idea of this construction is:

(a) External 0.025 annealled stainless steel shingles, using edge attachments permitting sizeable shear displacements (about 0.12 in. maximum), to accommodate the strains imposed by the temperature gradients.

(b) RF 300 insulation to protect the substructure from the heat and vibration. (Q-felt insulated better but corroded the adjacent metal in service.)

Revised and condensed by the author especially for the *Review* from a paper of the same title presented at the ARDC-sponsored Symposium on High-Speed Aerodynamics and Structures, University of Florida, Jan. 21–24, 1957.

The author is Chief Structures Engineer, Airplane Engineering Division.

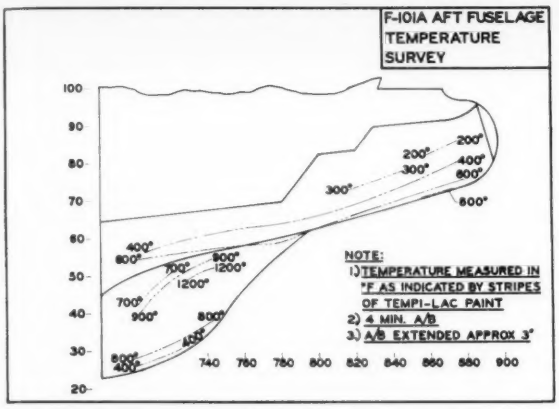

FIG. 1.

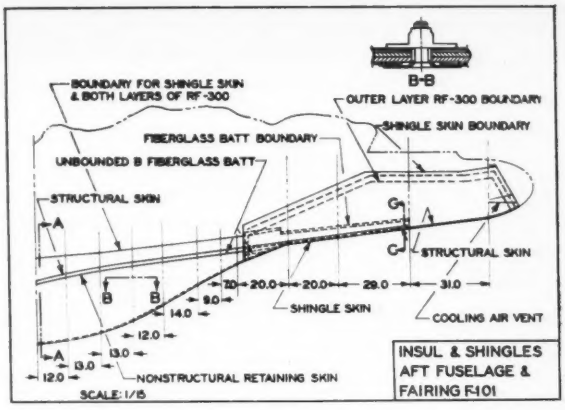

FIG. 2.

(c) Substructure. Where temperature peaks were less than 200°F., normal aluminum-alloy plate-stiffener construction was used, with gages of 0.064 or so. Where temperatures were higher, a two-sheet sandwich was used. The corrugated sheet is 0.016 titanium, and the adjacent flat sheet is 0.025 titanium.

Hundreds of ground and flight hours have been logged on blast fairings of this type. Intermittent use of afterburning produces the most severe environmental conditions.

This construction was developed because normal plate-stiffener construction was inadequate from both the thermal and sonic fatigue standpoints. It is expensive from the weight standpoint. Normal fuselage plate stiffener construction runs to about 1.4 lbs. per sq.ft., whereas the corresponding weight on the F-101 is 3.7 lbs. per sq.ft. in the blast area, which is 57 sq.ft.

Laminated fiberglass seemed to have interesting possibilities in this application. A blast fairing was built with a bonding resin advertised as having good high-temperature strength but delaminated after a few minutes of exposure to afterburner blast.

Elevated temperature tests on panels representative of a laminated fiberglass door considered for use on a missile indicated that delamination occurred at about 450°F. and was independent of bending stress existing in the material.

A missile wing and fin were tested at the critical combination of load and temperature. Fig. 3 is the test setup. One test involved raising the skin temperature to about 500°F. in about 25 sec., holding the temperature, and loading from zero to 110 per cent limit twice. Hysteresis was negligible. Buckles 0.15 in. deep remained in the aluminum-alloy skin after unloading. In a subsequent failing test at temperature, deflections and load at failure were nearly identical to those determined during a previous room temperature failing test.

The points which seem of most significance to this discussion are:

(a) The aluminum-alloy skin held up well beyond the temperature range in which it would normally be used for design, primarily because of the ability of the cooler, more temperature-resistant substructure to carry the load.

(b) The thermal strains did not induce any premature failure.

(c) Buckles remaining after limit thermal load conditions were sufficiently deep to be unacceptable aerodynamically for an airplane intended for repeated operation under such conditions.

Tolerable Strain Magnitudes

Structures which carry their loads in an environment such that Hooke's law is valid are said to be "in the elastic range." The inelastic or plastic range has been arbitrarily defined as that stress level above which the inelastic strain exceeds 0.002 in. per in., by the general acceptance of $\epsilon = 0.002$ as the criterion for yield stress. The thermoplastic range may be similarly defined as the combination of stress, time, and temperature above which inelastic strain exceeds 0.002.

A wing structure must be designed to keep the strains less than 0.005 in./in. in the bulk of its material. Local strains around rivet holes, etc., will unavoidably exceed 0.005. The necessity for keeping the average strain low is apparent when one considers the average strain present under conditions creating sizeable de-

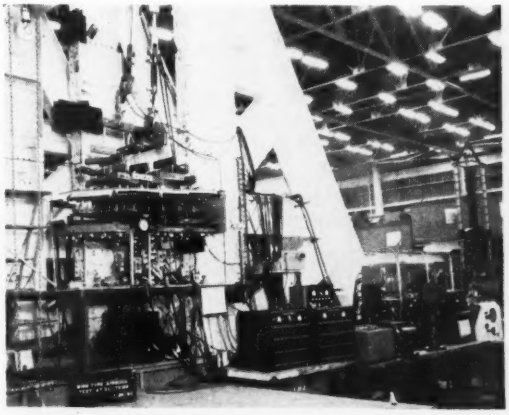

FIG. 3. Missile wing elevated temperature test setup.

flections. For instance, a fighter of 40-ft. span with thin wings will have a limit load tip bending deflection of 18 in. or so and a tip rotation under critical torque conditions of 2 to 6 deg. These deformations are sufficient to make some difference aerodynamically, and they produce appreciable effects on load distribution, control effectiveness, and static stability. These deformations are associated with an *average* stress on the order of 30,000 psi in aluminum alloy, hence are associated with an *average* strain on the order of 0.003 in./in. Thus the useful stress-temperature range of a material is limited substantially to the elastic range. Reference 4 arrives at similar conclusions.

This is not to infer that the extensive data gathered on creep and inelastic behavior involving strains above 0.005 in./in. are of no use. These data are needed for evaluation of structural situations in local regions of structures—either local hot spots or local highly stressed spots.

Deflection Characteristics of Joints

Table 1 shows the load-deflection characteristics of a few commonly used joints, together with characteristics of a few joints designed to have extreme deflection characteristics. (A point of interest in the test data from which Table 1 is obtained: The permanent set at no load after the application of each given load is fairly close to 50 per cent of the deflection at load for all joints reviewed. In all cases the permanent set fell within a band of 30 to 70 per cent of deflection at load for *all* load levels.)

At elevated temperatures, strain characteristics of basic materials are available for many environmental conditions. Few data are available on joints at elevated temperatures. Reference 5 supplies extensive information on four specific joints, one using 0.125 diameter 24ST rivets. Data from this reference are tabulated in Table 2, assuming allowable (design) limit load on the rivet is reduced at temperature according to the allowable tensile yield at $t = 0.5$ hour for the basic material.

Table 1
Lap Joint Deflection Characteristics*

Joint Design†	Ultimate Strength per Fastener, Lbs.	Deflection at 33% Ult.	Deflection at 67% Ult.
5/16 NAS 177-10 steel hi-shear rivet countersunk in 0.250 75 ST aluminum alloy	5,750	0.005	0.019
3/16 AN steel screw machine countersunk in 0.081 24ST	1,370	0.013	0.022
1/4 in. AN 509-416 steel screw machine countersunk in 0.081 24 ST	1,870	0.011	0.029
1/4 in. AN 509-416 screw in double dimpled 0.125 75 ST	2,488	0.008	0.017
1/4 in. AN 509-416 steel screw countersunk in 0.081 24 ST with 0.06 free thickness rubber strip clamped between sheets	870	0.048	0.102
3/16 DD6 flush 24 ST rivet in dimple countersunk 0.064 75 ST	1,277	0.006	0.017
3/16 Dill Lok-Scru countersunk in 0.050 24 ST; AN 509-1032 screw countersunk in 0.156 24 ST and threaded into Lok-Scru	1,320	0.007	0.020

* Room temperature.
† All fasteners are flush type.

Table 2
Deflection Characteristics of Joints in Aluminum-Alloy Sheet with 24ST Rivets

Temperature, °F.	Allowable Limit Load in the Joint (3-0.125 D)	Deflection at Load,* In. Short Time	Deflection at Load,* In. At $t = 1$ hour	Hours to Rupture
Room	750	0.0055	0.0055	...
300	620	0.004 est.	0.004 est.	1,000
400	550	0.0035	0.004	100
500	330	0.002	0.003	60

* Sum of elastic and plastic deformation, thermal expansion of specimen excluded.

Observation of the fact that the limit load deflections at elevated temperatures hold on above the temperature range at which the basic aluminum alloy is inferior to, say, titanium leads to the tentative conclusion that joint behavior at elevated temperatures is no worse than at room temperatures, when standard practice on allowable strength is followed.

Putting it another way, the fact that basic material strength falls off faster than stiffness with increasing temperature seems to apply to joints as well as to basic materials.

Considering that average duration of limit load is 10 sec. per application and that limit load is applied on the order of once in 10 hours, the hours to rupture at elevated temperature up to 400°F. are sufficiently high as to appear not limiting in design, presuming that aeroelastic effects have been properly accounted for.

The effects of creep at elevated temperature are a matter of concern. Presumably all aeroelastic cases would be variable with time if creep were significant. Using 2024ST-3 aluminum alloy as an example, the basic material is useful up to about 300° above which point other materials are used for various reasons. A structure designed to standard criteria will use reduced ultimate and yield allowables at temperature similar to Table 2. Survey of creep data at 300°F. indicates the short time ultimate strength begins to drop after about 100 hours of exposure, the short-time yield after about 1,000 hours, and 0.005 in./in. creep at yield stress occurs at upwards of 10 hours.

At 375°F., the ultimate begins to drop at 1 hour, the yield at 20 hours, and the stress for 0.005 in./in. creep is below yield stress for all exposure times, indicating that standard criteria are insufficient for design at this stage of thermoplasticity.

The effects are illustrated for extreme thermoplastic conditions by assuming a thin straight wing in aluminum alloy at 375°F., exposed to limit torque at temperature, and further assuming it has been designed to

TABLE 3
Tip Rotation Time History

Time	Tip Rotation, Deg.
0	7.0
30 min.	10.5
12.5 hours	17.5

zero margin for 375°F., short time allowables with no consideration for creep. The tip twist as a function of time is given in Table 3. (Room temperature tip rotation is 6.3°.)

This tip twist would not increase with time in a wing swept more than a few degrees because of bending interaction with torque.

The general observation to be drawn is that thermoplasticity renders aluminum alloy unfit for primary structural use much above 300°F. In composite structures where local thermoplasticity does not impair fit or function, aluminum alloy can be useful above 300°F. Similar general ranges can be established for other materials of construction.

Analogous considerations for attachments from reference 5 indicate that creep is insignificant to 100 hours at 300°F. but becomes significant at 1 to 10 hours at 400°F., indicating that joint characteristics will not be more limiting than the basic material.

WING TORQUE BOX DESIGN CONSIDERATIONS

Attachment deflections and slip have little significance in wing bending deformations. Visualize a spanwise strip of wing from root to tip. At 30,000 psi in aluminum alloy, the axial deformation of the strip for a 20-ft. semispan is almost an inch. Four spanwise joints at limit load could contribute as much as 5 per cent additional axial deformation of the strip—but in a normal design somewhat less. The same effect applies to materials other than aluminum.

On the other hand, the effect of attachment slip on torsional deformations may be considerably more significant. At room temperatures, wing of normal riveted and bolted construction have appreciable torsional plasticity due to slip and/or tolerances in the attachments. Considerable laboratory testing in which hysteresis was carefully measured indicated that joint tolerances were of no significance to bending deformations but quite significant in torsional deformations. During one wing twist investigation, a mid-aileron station rotation of 1.6° was measured at limit torque and a corresponding permanent torsional set of 0.6°. Based on this and other laboratory work, an empirical method of estimating the torsional permanent set of wing subjected to limit torque at the mid-aileron station was established:

$$\Delta\theta = \sum_0^s \frac{L_i \delta_{si} N_i}{(2ab)_i} \text{ radians} \qquad (1)$$

where the subscript indicates conditions in the ith spanwise wing segment; L = spanwise length of wing segment, in.; and δ_S = fastener slip = (0.011 D + 0.2 tolerance); and where tolerance = nominal hole diameter minus nominal fastener pin shank diameter; N = number of spanwise attachment seams contained in the torque box; and ab = cross-sectional area of the wing torque box, sq.in.

The summation is taken from root to the wing station at which the twist is desired.

This empirical formula predicted the observed permanent twist within ±30 per cent on all of several wings on three models tried. A rough idea of its significance may be gained by comparing the F-101 torsional permanent set of 0.6° at the mid-aileron station with the total twist under the critical rolling condition limit load of 3.5°. This was the closest tolerance wing of the three. Torsional hysteresis was more significant in the other types of wing investigated.

The results of wing torsional permanent set are illustrated in Fig. 4. This hypothetical wing at M = 1.6 has elastic characteristics such that the aileron reverses at 440 knots E.A.S. The airplane has adequate control up to 410 knots without any torsional permanent set, but the presence of set reduces the speed for adequate control to 375 knots.

COVER PLATE DESIGN CONSIDERATIONS

Reference 6 studies thermal strains and deformations assuming integral attachment between wing components and illustrates the thermal effects in terms of deflection and stress for several structural arrangements.

Without going into any detailed recomputations, the effects of attachment slip can be qualitatively evaluated.

The thermal bending deformations of a box beam are seen to arise primarily from the relative expansion of the top and bottom cover plates due to their difference in average temperature. Thus wings built of continuous (spanwise) top and bottom cover plates will display the calculated bending deformations regardless of flexibility or plasticity in the attachment of the cover plate to the substructure. Thermal bending deformations (as distinguished from bending deformations caused by applied loads) may be relieved by making the cover plates discontinuous spanwise. For a temperature differential top to bottom of the wing of 400°F., a spanwise relative deformation of about 0.045

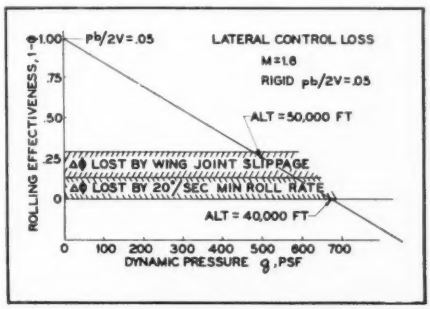

FIG. 4.

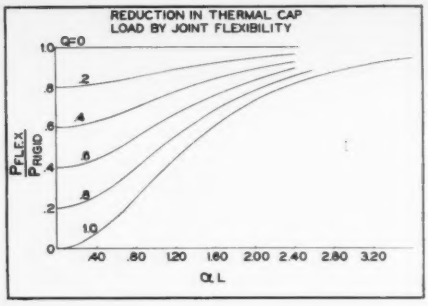

FIG. 5.

in. per ft. in stainless steel takes place. Thus a chordwise seam every 3 ft. with a slip characteristic of 0.135 in. would theoretically eliminate the entire thermal bending deformation. In actual practice the deformation will be only partially relieved since joints in structures never display "free slip" characteristics but slip regularly with load.

For bending deformations arising from combined thermal and load effects, flexible chordwise splices will load up the substructure at the expense of the cover plate. In the above case (temperature differential 400°F., 0.135 slip every 3 ft.) the flexibility of the chordwise splices would theoretically shift the entire bending load from cover plate to substructure. In practice, the wing would strike a balance between the load-strain characteristics of the cover plate and the continuous substructure, governed by the relative deformations of the two.

Turning to effect of attachment slip on stress: In Levy's example of Table 1 (reference 6), a peak tensile stress of 35,000 psi is observed. This arises from an imposed axial strain

$$\epsilon = 35{,}000/26{,}000{,}000 = 0.00134 \text{ in./in.}$$

and could be relieved by slip in chordwise splices as noted above or by slip in shear attachment of cover plate to spar. In the latter case, a total slip of 90 by 0.00134 = 0.12 in. would have to occur in a cover plate continuous spanwise for 15 ft. to relieve this stress entirely.

The Structural Research group developed a relationship between thermal stress induced in the spar cap and cover plate-to-cap attachment flexibility as follows:

$$P = \frac{(\Delta T)\,\gamma E A_2}{1 + (A_2/A_1)} \left[\frac{Q}{\cosh \alpha L} - 1 \right] \qquad (2)$$

where

$$Q = \frac{K_F E A_2}{1 + (A_2/A_1) + (K_F E A_2/L)}$$

$$\alpha = \sqrt{\frac{1}{K_W E A_2} \left(1 + \frac{A_2}{A_1}\right)}$$

P = thermal cap load, lbs.
ΔT = temperature difference between cap and skin, °F.
γ = thermal coefficient of explansion, in./in./°F.
K_F = flexibility of chordwise splice = $\delta/(f)\ (A)$, in./lb.
K_W = flexibility of skin to cap attachment = δ/q for joint, in./lb./in.
E = modulus of elasticity, psi
A_1 = skin area, sq.in.
A_2 = cap area, sq.in.
L = half the continuous length of cap or skin between discontinuities

The ratio of cap load with flexible cover plate-to-cap joints to that with infinitely rigid joints is plotted in Fig. 5. The load-deflection characteristic of a joint is assumed linear for Eq. (2) and Fig. 5. Actual joint extension characteristics as given in Table 1 demonstrate the nonlinearity of the load-extension plot. Therefore it is necessary when using Eq. (2) and Fig. 5 for design to select joint flexibilities K_W and K_F as secant values intersecting the actual load-extension plot of the joint in question at the operating load of the aeroelastic case under consideration.

Several cases are worked out in Table 4. Continuous skin and caps with a normally tight fastener (1/4-in. screw machine countersunk in 0.081 aluminum alloy) offer only an 8 per cent reduction in thermal cap load. The most extreme case shown breaks the cap every 10 in. with a 95 per cent reduction in thermal cap load.

Use of this method in design requires a knowledge of joint deflection characteristics at the elevated temperature under consideration. In the absence of specific data, and in view of the spot check of Table 2, the fol-

TABLE 4
Thermal Cap Load Reductions
(Cap area = 0.75 sq.in.; skin area = 2.5 sq.in.)

Skin Splice Elasticity, In. at Stress	Deflection, Skin to Spar Splice, Lbs./In.	Cap Splice	In./Lb. K_F	Lbs./Sq.In. $1/K_W$	L, In.	$K_F E A_2 / L$	Q	αL	P_F/P_R
0.02 at 20,000 psi	0.1 at 2,500	None	$\frac{1}{250{,}000}$	25,000	12.5	2.4	0.65	0.823	0.523
None	0.1 at 2,500	0 lbs./in.	∞	25,000	5.0	∞	1.0	0.33	0.052
0.019 at 20,000 psi	0.029 at 2,500	None	$\frac{1}{2{,}630{,}000}$	86,200	12.5	0.228	0.15	1.53	0.94
0.019 at 20,000 psi	0.029 at 2,500	0.019 at 20,000 psi	$\frac{1}{607{,}000}$	86,200	12.5	0.989	0.392	1.53	0.82
None	0.029 at 2,500	0 lbs./in.	∞	86,200	5.0	∞	1.0	0.61	0.16

TABLE 5
Wing Cover Plate Weights

Construction	Cover Plate Weight/ Airplane	Estimated Peak Temperature Feasible, °F. — Short Time	Long Time
(a) Aluminum alloy	1,262	350	300
(b) Aluminum-alloy insulated	1,666	1,200	300
(c) Titanium	1,388	900	800
(d) Stainless steel	1,596	1,400	1,200

lowing assumption seems sufficiently accurate: The deflection of any joint at elevated temperature is the same as the room temperature deflection at any given percentage of yield load. (Short-time yield load for both room and elevated temperature.)

It should be noted that the use of dissimilar materials has a powerful effect in altering thermal cap load. Eq. (2) provides a means of evaluation, but no cases are worked out in this paper.

It is seen that some relief of thermal stresses is obtained by the plasticity inherent in normal rivets and bolts and that selection of attachments with larger than normal tolerances can be used to alleviate internal strains. These will have repercussions on the aeroelastic effects.

Conversely, it appears that only integral or equivalent—i.e., bonded or spotwelded—structures will actually attain the theoretical thermal stresses.

Wing Cover Plate Weights

A brief study of the relative weight of high-temperature construction versus low-temperature insulated construction was made. Using a thin, low aspect ratio, swept wing, the weight of cover plates was estimated for four cases:

(a) Aluminum-alloy, normal heavy-piate multicell construction.

(b) Construction (a) plus an 0.19 insulation layer, plus 0.025 stainless steel cover, construction details similar to F-101 blast fairing.

(c) Titanium construction similar to the aluminum alloy, designed for adequate strength and stiffness.

(d) Stainless steel per (c).

Results are given in Table 5.

It appears that handling the heat problem by insulation (of this sort, at least) is less desirable, from the weight standpoint, than selecting a heavier material which can do the job without insulation. However, other benefits might be obtained from this type of construction, such as keeping equipment or fuel cooler longer.

Skin Panels

Design of individual panels poses a problem. Skin buckles, either temporary during periods of temperature gradient or permanent, as a result of plastic behavior during temperature-load conditions, are an annoyance. While they may make little difference to the overall aeroelastic behavior of the wing, they have some aerodynamic effect on drag; if nothing else, they form fatigue nuclei and are unsightly. High-performance airplanes capable of penetrating the thermal thicket will normally have heavy wing box cover plates. Buckling stresses for such plates are readily calculable. It would appear that provision for a certain amount of joint movement would eliminate the buckles. In the writer's experience this is not feasible.

Sandwich construction seems to offer a promising solution. Bonded construction of the type now in general use loses its strength at 300° to 400°F. (comes unbonded) so it has a limited application. Various mechanical sandwiches have demonstrated their adequacy for elevated temperatures. The most promising sandwich, and one which has only recently come into use, is stainless steel honeycomb. In this construction, thin face plates are brazed to a honeycomb core. Typical dimensions are 0.25 to 1.0 total thickness, 0.025 face plates, 0.002 foil core, and 0.01 thickness of brazing. Fig. 6 shows the blown-up edge of a stainless steel honeycomb sandwich of 0.3 in.-total thickness built by Solar Aircraft Company.

While no elevated temperature test results are available to the writer, panels of this material were exposed to sonic fatigue conditions and stood up well. In theory, this sandwich should behave well under thermal conditions. Overall panel deformations will occur when the outer plate is at a different temperature than the inner. However it would appear that internal thermal strains would be negligible; the honeycomb can accommodate them without reducing its shear carrying ability. Edging details are difficult but can be developed.

Spar Construction

Construction details of spars which have certain advantages at elevated temperatures are shown in Fig. 7. The webs built with open-ended corrugations are the point of interest. This design was developed for producibility but has certain advantages over the usual flat sheet webs from the thermal standpoint. In the

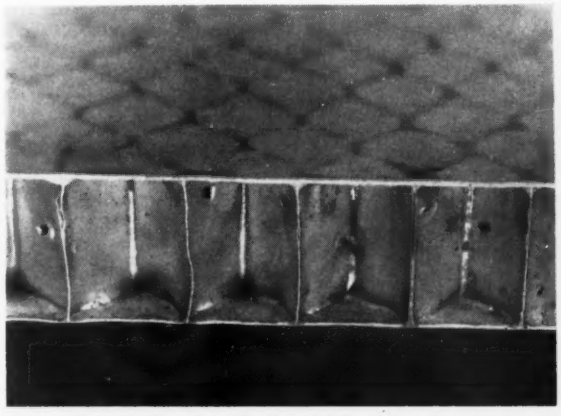

FIG. 6. Stainless steel brazed honeycomb, 9 times size.

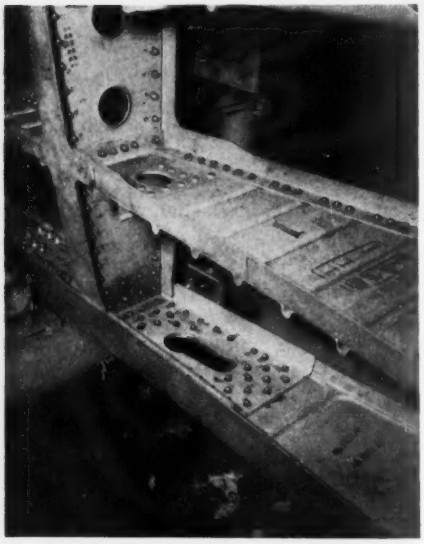

FIG. 7. F-101 spar construction.

presence of temperature gradients, the webs themselves should be substantially strain-free as a result of their axial flexibility due to the corrugations. This construction is of little help in relieving relative strain between cover plate and spar cap.

The spar web construction shown is giving good service in F-101's so it should cause no unusual alarm from the standpoint of other structural considerations.

Reference 7 suggests a similar web-cap arrangement, in which the cap is scalloped to reduce thermal strains further, and another construction method in which the web is fastened to the cover plate by individual angle clips. The latter will relieve cap to cover strains completely, as indicated by Fig. 5, but has the disadvantages of considerably greater shear flexibility and consequent loss in GJ, a slight loss in structural efficiency, and perhaps higher production costs.

The open-ended bead construction of Fig. 7 has all the characteristics necessary for proper behavior of webs at nonuniform elevated temperatures. Stress alleviation from fastener slip is unnecessary with such webs.

LEADING AND TRAILING-EDGE STRUCTURE

Normally, these structures function only to carry distributed loads into the primary wing torque box.

Reference 8 discusses wing structural behavior from the standpoint of torsional stiffness during rapidly changing Mach Numbers. The treatment is inadequate since it discusses the effective torsional stiffness only at one specific point in the torque-twist relationship. Torsional stiffness is shown to be tremendously reduced because of the temperature-induced compression in the leading and trailing edges. The treatment does not indicate that the reduction is effective over a small twist angle and on either side of the twist angle has higher values. The effect is apparent in the vibration data of this article.

This effect can cause drastic aeroelastic results in wings which are integral root to tip and leading edge to trailing edge. While divergence will probably not be affected (since the wing will twist beyond the angle of low stiffness and then stiffen up), the spanwise loadings will be altered by the wash-in or wash-out induced by the strain pattern. Consequently longitudinal stability will be affected. Flutter speeds will be reduced in a manner analogous to introducing a free play torsionally into the wing. The introduction of this effect into flutter calculations is difficult, to say the least. This effect will produce unacceptable lateral control characteristics for lateral control systems with high twisting moment coefficients; when the pilot changes from left roll to right roll, the region of reduced elasticity will show up as a momentary sluggishness. The region of reduced lateral control is variable with dynamic pressure and Mach Number, will appear haphazard to the pilot, and will make the lateral control intolerable for precision flying.

These considerations all lead to the conclusion that relative deformation should be permitted between leading edge and wing box and between trailing edge and wing box. A crude estimate based on the treatment in reference 8 indicates that relieving the forward 15 per cent and the aft 30 per cent of the wing of axial continuity should permit retention of over 80 per cent of the GJ which reference 8 indicates is lost by this effect. The approximately 20 per cent loss in effective torsional stiffness is still over a relatively small twist angle; and integration of the effective GJ over, say, $\pm 2°$, which is a range of significance in the computation of aeroelastic effects, will result in a still smaller reduction.

A straightforward method of removing axial strain continuity in leading-edge structure is to support it by piano hinges top and bottom.

The F-101 leading edge (15 per cent of chord) is supported this way, as shown in Fig. 8, and does its job structurally, as well as having good producibility and access to hydraulics and controls forward of the front spar. In this application, one hinge serves as a leading-

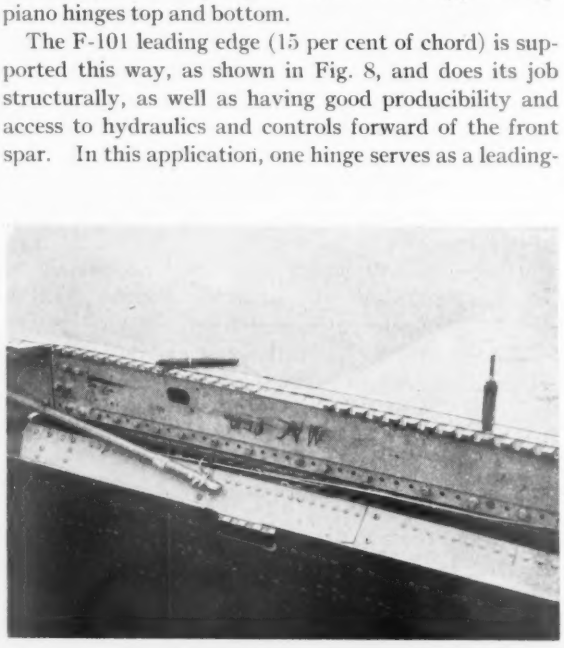

FIG. 8. F-101 hinged leading edge.

edge torque box cap. Any specific amount of axial play can be designed into the arrangement by making each hinge tange the desired amount narrower than its mating recess.

If the entire trailing edge of a wing is devoted to flaps, ailerons, etc., the necessary lack of axial continuity is automatically provided. If not, the fixed trailing-edge panels can be supported by piano hinges also.

Obviously various kinds of loose-fit fasteners, such as that shown in Fig. 2, can be used in this application, and each has its associated design problems.

Use of these suggested design arrangements will substantially eliminate the reduced torsional stiffness induced by compressive thermal strains in the forward and aft sections of the wing torque box, resisted by tensile strains in the box near mid-chord. If aerothermo-elastic behavior has been predicted upon the wing torque box alone supplying the entire wing strength and stiffness, little is lost by the leading- and trailing-edge structure lacking axial continuity or lacking shear rigidity in its attachment to the wing box.

Structural Optimization

An area of interest in future design development is structural optimization from the standpoint of high-temperature materials versus insulation versus heat suppression, diversion, and removal techniques. Many studies and investigations have been made to bring out individual and combined effects of various approaches. These include the use of porous media with a cooling effluent, nose spikes and vortex generators to change the boundary-layer character, and a leading-edge heat sink. Various types and arrangements of insulating material have been suggested: external covering of low conductance materials and coverings of semimetallic materials with advantageous evaporative and sublimation qualities at high temperature.

These concepts offer a tremendous number of combinations to the ingenious designer seeking to optimize a given structure. The optimization of any particular structure is heavily dependent on its operating regime. If it is to operate for only a minute or so at extreme temperature, cooling effluents are probably a minimum weight treatment. For slightly longer times at temperature, external insulation and/or heat sinks may be lightest. For extended periods at temperature, it appears almost certain that use of high-temperature material will produce the lightest design. Boundary-layer control may be advantageous in all regimes, or it may lose out when compromised against performance loss.

Having developed such optimizations, the designer still has formidable problems facing him. Should cooling devices be installed at the hot spot or remotely? Should heat sinks or effluent sources be panels or spanwise strips? Where can the mechanical equipment and exotic fabrications of material be obtained in time to qualify and use them?

These same considerations apply with more or less force to the mechanical, electrical, and electronic equipment. In the writer's experience, it appears that the heaviest weight penalties in the near future for aircraft operating in the thermal thicket may arise from lack of suitable equipment. The first reaction of the equipment manufacturer, when posed a temperature problem, is "cool it!" This is without a doubt the heavier approach; redesign of the wiring, coils, tubes, bearings, seals, insulation, paint, valves, microswitches, working fluids, solenoids, relays, etc., for higher temperature operation is almost certain to be lighter than addition of a refrigeration system. At sufficiently high temperatures, of course, both high-temperature construction and refrigeration will become necessary.

Conclusions

A review has been made of certain structural problems associated with elevated temperatures. Methods of construction have been discussed which can be used to eliminate or ameliorate these structural problems. It appears design arrangements suitable for elevated temperatures to 1,200°F. or so are available or under development, and the fundamental problem remains substantially the same as in the past: selection of the minimum weight materials, structural arrangements, and methods of construction to obtain the lightest possible structure with adequate aeroelastic and other strength characteristics.

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Compressor stall as a limit of engine performance and the methods of analysis for the prediction of the stall limits are discussed.

Some Effects of Inlet Pressure and Temperature Transients on Turbojet Engines

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Symbols

C	=	capacitance, $V/\gamma RT$
G	=	constant
N	=	engine speed, r.p.m.
P	=	pressure, lb./sq.ft.
R	=	gas constant, ft.lb./(lb.)(°R.)
s	=	Laplacian operator
T	=	temperature, °R.
t	=	time, sec.
U	=	axial velocity, ft./sec.
V	=	volume, cu.ft.
W	=	weight flow, lb./sec.
X	=	distance from compressor inlet, ft.
α, β	=	constants
γ	=	ratio of specific heats
φ	=	phase shift, deg.
Δ	=	denotes change from steady state
η_c	=	compressor efficiency
τ	=	time constant, sec.

Subscripts

s	=	static
x	=	refers to a station within compressor
1 to 10	=	stations in engine (see Fig. 3)
ss	=	steady state

Introduction

THERE ARE MANY KINDS of transient disturbances which affect the operation of turbojet engines in flight. For simplicity these disturbances may be roughly divided into transients which are slow enough to be compensated for by the usual engine controls and transients which are significantly faster than the control.

Changes in engine-operating or environmental conditions which occur in about a tenth of a second or more, or in oscillatory cycles of less than 1 cps, fall within the slow or controllable group of disturbances. For these slow disturbances engine operation is essentially similar to steady-state operation (quasi-steady). Engine response and operating limits for these disturbances may therefore be predicted from the steady-state performance. These controllable transients will not be discussed further herein.

The faster transients which may occur in considerably less than a tenth of a second or at frequencies from 3 to over 100 cps are also of great importance. Examples of such transients are environmental changes in inlet temperature or pressure which may occur as a result of operation of variable-area inlet diffusers, diffuser buzz, flying through wakes caused by armament firing, flying through shock waves, and several others. These disturbances may cause rates of change in engine inlet temperature as high as 10,000° per sec. or pulsations in inlet pressure as rapid as 100 cps.

It is the purpose of this paper to show some of the effects of these very rapid transients on turbojet engine operation and to develop analytical methods of predicting the effects. For simplicity, effects of changes in inlet temperature and pressure are treated separately although they may occur simultaneously in some cases.

Results of exploratory engine tests which show the general nature of engine response to rapid inlet transients are discussed. On the basis of an assumed dynamical model of an engine a method of analysis of engine response is derived and checked against experimental data. The calculated effects on engine operating limits of transients in inlet pressure and temperature are shown for two typical examples.

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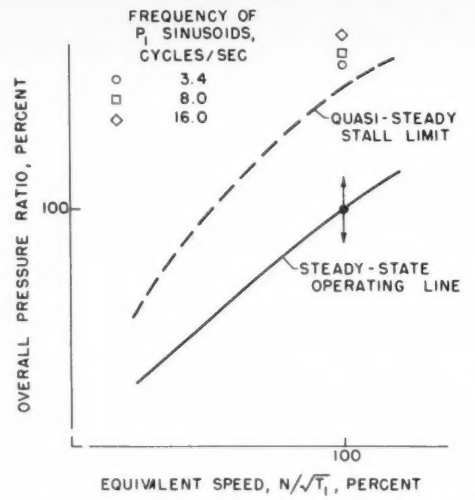

FIG. 1. Comparison of stall limits with inlet pressure sinusoids and quasi-steady stall limits.

Exploratory Experiments

To investigate the effects of inlet pressure and temperature transients on turbojet engines, full-scale engine tests were made in an altitude test facility in which controllable ram air could be supplied to the engine inlet.

For the inlet pressure transient test, ram air was supplied to the engine through a double duct with a rotating valve ahead of the compressor. The rotating valve had 20 spokes which alternately covered and uncovered areas of the inlet duct of high and low pressure. Rotation of the valve thereby produced a nearly sinusoidal oscillation in compressor-inlet pressure. By varying the speed of rotation, a range of frequencies from about 2 to 70 cps could be covered. Variation of the pressure upstream of the valve resulted in inlet pressure amplitudes up to a maximum of about 100 per cent.

At various constant frequencies the amplitude of compressor-inlet pressure was increased until compressor stall was encountered. The occurrence of stall was accompanied by a sudden large increase in the magnitude of engine vibration and by a large increase in turbine inlet temperatures thereby making the stall limit a true limit of safe engine operation.

In the past, discussion and analysis of compressor stall limits have been made with reference to compressor maps obtained during quasi-steady operation. The relation of the stall limits, encountered during inlet pressure transients, to these quasi-steady stall limits is shown in Fig. 1. For transients initiated at rated engine speed, indicated by the solid data point, the compressor stalled at the conditions denoted by the symbols for a range of frequencies. As indicated by the data points, the compressor stalled at conditions of overall pressure ratios higher than the quasi-steady stall limit. It is clear, therefore, that steady-state compressor performance is no criterion of stall for inlet pressure oscillations at frequencies of 3 cps and higher.

For the inlet temperature transient tests, ram air was supplied to the engine either through a duct containing a preheater or from the surrounding air. During normal operation the hot air supplied by the preheater was by-passed around the engine. To introduce an inlet temperature transient, quick-opening valves in the preheater duct were activated, shutting off the by-pass and allowing the hot air to be ingested by the engine. The transients obtained in this manner were essentially "ramps" (linear increase of temperature with time) which could be varied in slope from approximately 2,000° to 10,000° per sec.

Inlet temperature ramps were introduced to the engine at increasing rates until compressor stall was encountered. As in the case of inlet pressure transients, compressor stall was a real limit of safe operation in the case of temperature transients not only due to vibration and increased temperature, but in addition, stall was frequently accompanied by combustor blowout.

The relation of the stall limits to the quasi-steady stall limits is shown in Fig. 2. For ramps in inlet temperature of various slopes starting at rated engine conditions, the compressor stalled at the conditions indicated by the symbols. It is evident that, as in the case of rapid inlet pressure oscillations, the compressor does not stall at the quasi-steady stall limit so that again steady-state compressor performance is no criterion of compressor operating limits during rapid inlet temperature transients.

ANALYSIS

As was demonstrated by experimental data, it is incorrect to assume that the compressor acts as a unit for rapid inlet transients as it does for quasi-steady operation. To provide an explanation of the stall limits observed and to devise a method of predicting these limits it is necessary to determine the changes in pressure, temperature, and flow as they propagate through the compressor or, in other words, determine their variation with time at various stations in the compressor. In the subsequent sections this is done by

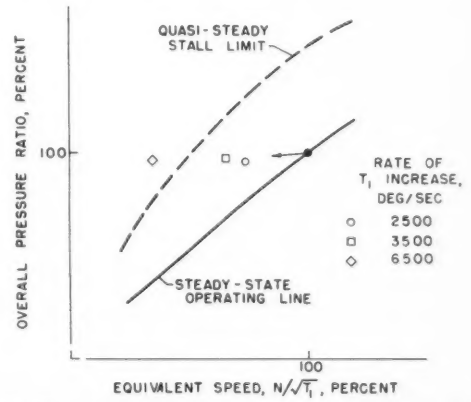

FIG. 2. Comparison of stall limits with inlet temperature ramps and quasi-steady stall limits.

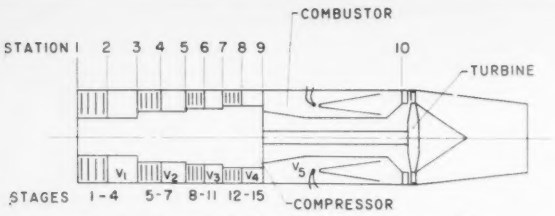

FIG. 3. Schematic of dynamical engine model.

adapting a dynamical model of an engine and comparing the results computed on the basis of this model with the experimental observations.

The Dynamical Model

The compressor of the dynamical model is considered to be composed of a series of elements, as shown in Fig. 3. Each element represents a group of stages within which the steady-state variations of flow, pressure, and temperature are assumed to hold. Each element is followed by a volume equivalent to that of the preceding stage group and representing the dynamical elements of the flow. The combustor is assumed to have the dynamics of its equivalent volume and the turbine is assumed to have no dynamics.

The compressor could have been broken into any number of groups, depending on the degree of resolution required in the analysis. Four groups were chosen for this problem as an arbitrary assumption and because test data to verify the analysis were available for the particular groups used.

Steady-State Stage Group Characteristics

As developed in numerous sources in the literature on compressors, the performance of a group of compressor stages can be generalized as shown in Fig. 4. For a constant engine speed the average stage group outlet pressure is related to the inlet flow, pressure, and temperature, as indicated in the figure. Because of this generalization, the following equation for the steady-state performance of a group of stages may be written

$$P_2 = f_1(P_1, T_1, W_1) \tag{1}$$

Alternately, if stage group efficiency is assumed constant,

$$T_2 = g_1(P_1, T_1, W_1) \tag{2}$$

In this analysis it is assumed that within each stage group of the dynamical model these steady-state characteristics hold for all transients. Of particular importance is the stall point noted on the stage group characteristic curve of Fig. 4. Numerous experiments have shown (at least near rated engine speed) that during a transient when the operating point of a group of stages reaches the stage group stall limit, stall of the whole compressor is initiated. When this stall occurs at high speeds, it is usually followed by compressor surge and other inoperable engine conditions as previously discussed. Throughout the analyses then, the engine stall limit will be taken as the point at which any one of the stage group reaches its individual stall limit. It is, therefore, the purpose of the analysis to show how the operating point of each stage group departs from equilibrium in the presence of an inlet transient disturbance and to find the conditions of this disturbance in inlet conditions which will cause stall.

Stage Group Dynamics

The dynamics of the volumes V_1–V_5 are computed by a method similar to that of reference 1 and on the basis of the following assumptions.

(1) Heat transfer from the gas to the metal is neglected.

(2) Only small changes in stage conditions occur in the volume so that the isentropic relation between pressure and temperature is valid.

(3) Changes in pressure and temperature are instantaneously propagated throughout the volume so that any change in density of the fluid within the volume with time is dependent only on the change in the mass of the fluid within the volume with time.

With these assumptions the following equation may be derived.

$$(V/\gamma R\bar{T})(dP_s/dt) = W_{in} - W_{out} \tag{3}$$

where the quantities P_s and T denote static pressure and average temperature in the volume, V, under consideration, and W_{in} and W_{out} are the instantaneous flows into and out of the volume. Of course, at any instant of time the flows into or out of a volume must satisfy the steady-state characteristics of the stage group upstream and downstream of the volume or, in other words, must satisfy equations similar to (1) or (2).

Combination of Eqs. (1) and (3) for each of the five volumes of Fig. 3 will result in a series of simultaneous differential equations. The exact numerical solution of these equations is a laborious and time-consuming

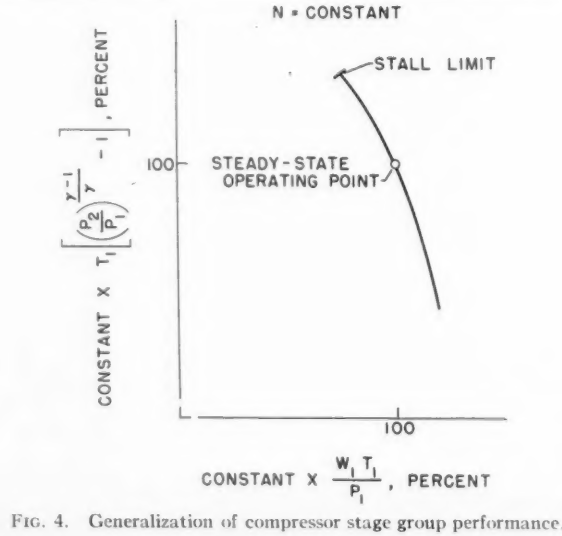

FIG. 4. Generalization of compressor stage group performance.

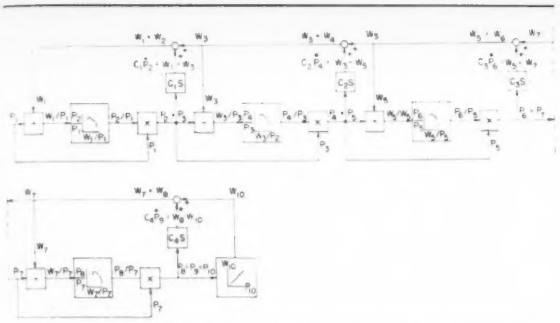

FIG. 5. Block diagram of analog computer arrangement.

process even with the aid of digital computers. Consequently, more convenient methods of solution were sought.

Methods of Solution

A preliminary study showed that for transients in inlet temperature certain simplifying assumptions could be made which were not valid for large inlet pressure transients. Consequently, different methods of solution were used for pressure and temperature transients.

Inlet Pressure Transients—Inlet pressure variations of interest cover a range of frequencies up to about 100 cps and amplitudes up to 100 per cent. To cover such a wide range of transients a complete solution was required. An electronic analog computer was therefore used to arrive at a solution.

A simplified form of Eq. (1) was introduced into the computer by the use of function generators. The simplification results from the fact that, for a constant compressor inlet temperature, any stage group inlet temperature depends only on the pressure ratio of the preceding stage groups. It is therefore possible to reduce Eq. (1) to the form

$$P_{x+1}/P_x = f_1(W_x/P_x)f_2(P_x/P_{x-1}) \qquad (4)$$

where the function f_2 was evaluated from experimental data.

Eq. (4) is combined with Eq. (3) by the use of suitable function generators and differentiating circuits as shown in Fig. 5. In applying Eq. (3) the derivative dP_s/dt is assumed identical with dP/dt. Although this may at first seem to be an invalid assumption, it may be reasoned that the error involved is negligible. To provide inlet and exit pressures as required, dividers and multipliers were used as shown in Fig. 5.

The discharge pressure of each stage group was fed to the next group and also to a differentiator to simulate the operation as indicated by Eq. (3). The flow through the turbine was considered choked which resulted in a flow proportional to compressor outlet pressure (assuming turbine inlet temperature constant). The constant of proportionality was determined from experimental data and the resultant straight line relationship was used to close the circuit.

In order to stabilize the system on the computer, it was necessary to introduce additional dynamic elements in each loop. These were chosen and the problem was scaled so that valid results could be obtained for the range of frequencies discussed previously.

The overall compressor frequency response obtained from the analog simulation is compared with test data in Fig. 6. The agreement between the data is excellent, indicating that at least at low inlet pressure amplitudes the assumed dynamical model and method of calculation are adequate to describe the phenomena occurring. As indicated in Fig. 6 the amplitude of pressure oscillation is attenuated with distance from the compressor inlet as frequency is increased. This attenuation of pressure, coupled with a phase lag, results in an oscillation of the pressure ratio across a group of stages in some complex manner varying for each stage. Because of this difference in variation between stage groups and because the margin between the steady-state and stall pressure ratio varies between stage groups, no general rule exists for determining the stage which stalls first.

In the analog study the amplitude of the inlet pressure oscillation was increased at various constant frequencies until stall of any stage group was encountered. The comparison of the stall limits computed in this manner with experimentally determined stall limits is shown in Fig. 7. Excellent agreement is obtained over the entire frequency range covered by the experimental data. It may be concluded that the model and method of analysis are also adequate for large amplitudes of inlet pressure oscillations. There appears to be every reason to believe that the analysis is general and would apply to any engine, at least in the frequency range from about 3 to 60 cps.

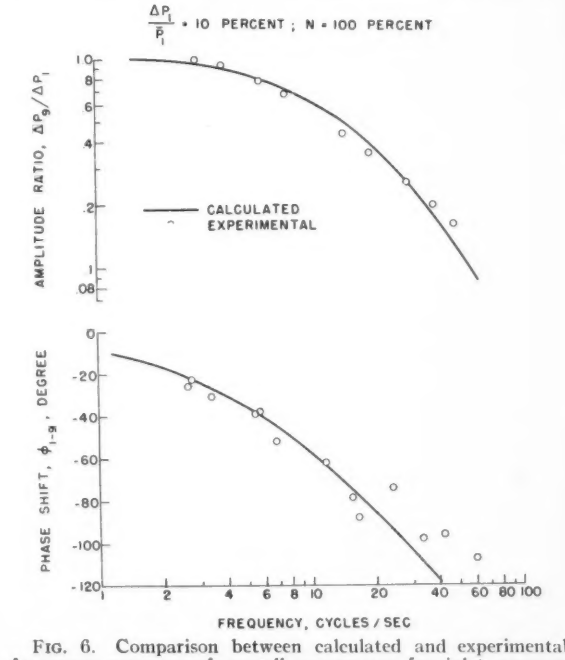

FIG. 6. Comparison between calculated and experimental frequency response of overall compressor for inlet pressure sinusoids.

Inlet Temperature Transients—The inlet temperature transients of particular interest are ramps with slopes in the range from 2,000° to 10,000° per sec. Available information revealed that for these rates the time from the origination of the transient until the compressor stalled was very small, on the order of 0.04 sec. or less. A preliminary study indicated that under these conditions the change in pressure in the compressor with time should be small.

These results suggested the tentative hypothesis that an adequate approximate solution might be obtained by assuming that changes with time in conditions downstream of the stage group being analyzed may be neglected. For the first step to the solution a simplification was made to the stage group characteristic curve. If the stage group efficiency is assumed constant, the coordinates of the characteristic curve can be converted to the form shown in Fig. 8. As a first approximation the characteristic curve can be assumed to be linear which then would result in the equation

$$T_2 - T_1 = \alpha_1 + \beta_1(W_1T_1/P_1) \qquad (5)$$

where α_1 and β_1 are the intercept and slope of the characteristic curve.

The general linearized equation of flow can be written

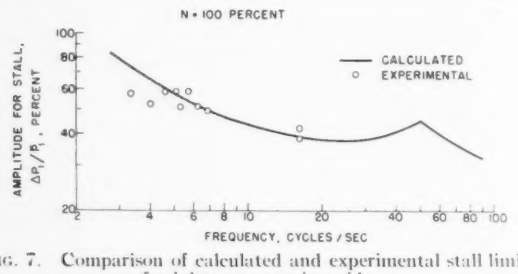

FIG. 7. Comparison of calculated and experimental stall limits for inlet pressure sinusoids.

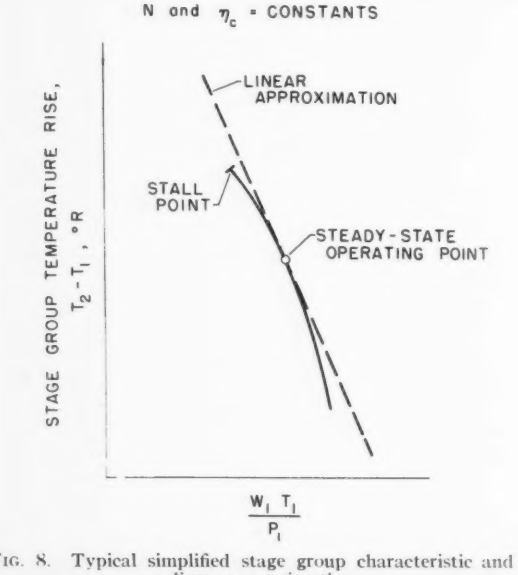

FIG. 8. Typical simplified stage group characteristic and its linear approximation.

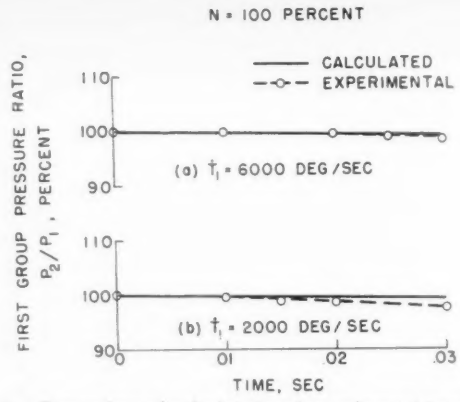

FIG. 9. Comparison of calculated and experimental interstage pressure response to inlet temperature ramps.

$$\Delta W = (\partial W/\partial P)|_{ss}\Delta P + (\partial W/\partial T)|_{ss}\Delta T \qquad (6)$$

and combination of Eqs. (5) and (6) with Eq. (3) yields the simple Laplacian equation

$$\Delta P_2/\Delta T_1 = G/[1 + (\tau)s] \qquad (7)$$

where the constant G and the time constant τ can be evaluated from steady-state characteristics. The complete derivation of Eq. (7) can be found in reference 2.

To test the validity of the assumptions used in deriving Eq. (7), the solution of the equation for ramp changes in compressor inlet temperature is compared with experimental data in Fig. 9. The figure shows the variation in pressure ratio of the first-stage group with time for inlet temperature ramps of 2,000° and 6,000° per sec. The very close agreement between the experimental and calculated results (also obtained for other test conditions not shown) indicates that at least for the first 0.03 sec. after the introduction of the transient the assumptions made in the derivation of Eq. (7) are valid. In addition, the results show that the changes in pressure ratio with time are very small. It may be concluded, therefore, that for at least 0.03 sec. after the introduction of a transient in inlet temperature at a rate in excess of 2,000° per sec. the change in pressure within the compressor is negligible.

This important result leads to a further simplification. It may be assumed that the changes in temperature within the compressor with time for these inlet temperature transients are not a function of pressure ratio. The transfer function from any group interstage temperature to the inlet temperature may therefore be written as follows:

$$T_x/T_1 = (\partial T_x/\partial T_1)|_{ss}/[1 + (\tau)s] \qquad (8)$$

where subscript x refers to any interstage station and subscript ss refers to steady-state conditions. It can be shown that the time constant τ may be closely approximated by $\tau = X/\gamma U_x$ where X is the axial distance from the compressor inlet to the station in question and U_x is the average axial gas velocity in the compressor.

The solution of Eq. (8) for the desired inlet tempera-

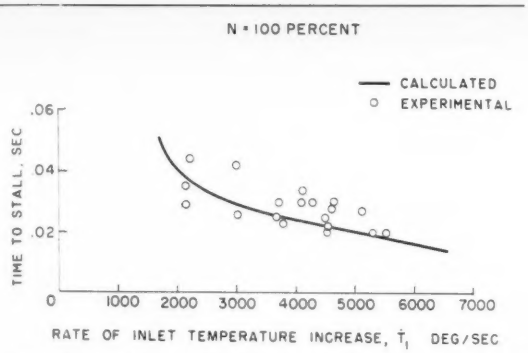

FIG. 10. Comparison between calculated and experimental stall limits with inlet temperature ramps.

ture transient will permit the calculation of the inlet temperature at any stage as a function of time. From the type of stage characteristics as shown in Fig. 4, the computed transient stage inlet temperature values, and the known steady-state value of stage pressure ratio, the stage inlet temperature may be computed; therefore, the time for stage and hence compressor stall can be determined.

In the full-scale engine tests, interstage transient temperature measurements were not made. The only available check on the accuracy of the analysis is, therefore, the comparison between calculated and experimental time to reach compressor stall after the introduction of a ramp increase in compressor-inlet temperature. This comparison is shown in Fig. 10. Considering the difficulty in experimental measurements of pressures and temperatures for these extremely short times, the agreement between calculated and experimental results is good. It may therefore be concluded that, at least for the engine tested, the method of analysis is sufficiently accurate to predict stall limits in the presence of linear inlet-temperature increases in the range above 2,000° per sec.

Typical Examples

To illustrate the results of the analysis and to show the potential importance of the effects of inlet temperature and pressure transients, two examples have been chosen out of the many possible in flight disturbances.

Diffuser Buzz—The first example is the reaction of the engine to diffuser buzz. It is well known that the operation of an engine inlet diffuser at off-design conditions may result in large high-frequency engine inlet pressure oscillations called buzz. The amplitude and frequency of buzz depend on the particular inlet design and on the engine operating conditions.

A typical buzz amplitude-frequency plot is shown in Fig. 11. Operation along the line shown might be encountered, for example, if the engine throttle is suddenly retarded at high flight speed. As the engine speed starts to drop, the engine airflow decreases and the diffuser departs from its design airflow. As the airflow falls, the amplitude and frequency of buzz increase as shown. As indicated by the computed stall line plotted in the figure, the compressor would stall when a buzz frequency of about 20 cps and an amplitude of about 40 per cent were reached. The analysis, therefore, makes it possible to determine the limiting conditions of engine operation during diffuser buzz. Of course, the method of analysis may be applied to determine stall limits for a wide variety of other inlet pressure disturbances also.

Inlet Temperature Ramps—To illustrate the large difference between the results of the transient analysis of inlet temperature ramps and the results that would be obtained from a quasi-steady analysis of the same inlet temperature ramps, Fig. 12 is shown. The stall limit for quasi-steady operation was computed by a method which has been widely used in the past which assumes that the overall steady-state stall limits apply. It was also assumed that the compressor pressure ratio departed from steady-state because of a change in compressor equivalent speed combined with a change in turbine-inlet temperature due to the reduction in airflow at constant fuel flow accompanying the reduced equivalent speed. The stall limits for the transient analysis were, of course, computed by the methods used in the analysis section.

It is evident that the quasi-steady analysis may be in error by as much as a factor of 3 in the limiting inlet temperature for stall. The use of the transient analysis is, therefore, required to determine stall limits with reasonable engineering accuracy.

(*Continued on page 68*)

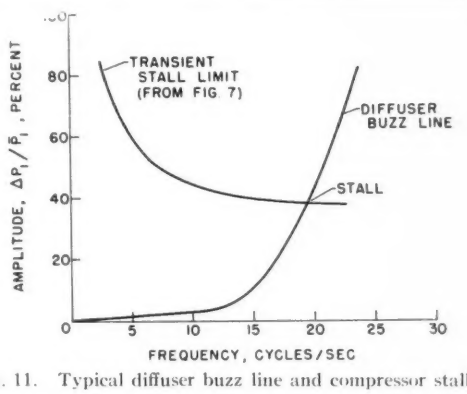

FIG. 11. Typical diffuser buzz line and compressor stall limit.

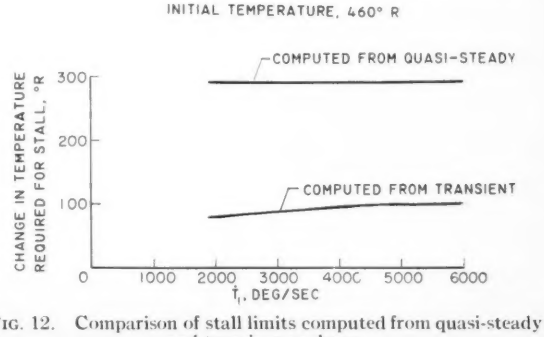

FIG. 12. Comparison of stall limits computed from quasi-steady and transient analyses.

The effects of altitude and ambient temperature in hovering and in forward flight are considered, and performance capabilities are evaluated. The conventional helicopter and STOL aircraft are also included, and the advantage of using special test aircraft is shown.

Evaluation of VTOL Systems Suitable for Transport Aircraft

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Vertol Aircraft Corporation

Introduction

The pay-load - range capability at various cruising speeds and altitudes is used as the basis for establishing the competitive positions of various VTOL systems with reference to their suitability for transport applications. However, the pay-load - range capabilities may also depend on such operational conditions as hovering time, altitude, temperature, etc.[1]

As to the time in hovering, the true VTOL transport aircraft should be able to remain in this regime of flight (or near it) long enough to assure the necessary freedom of decision at take-off and especially in landing. A 5-min. time in hovering is hence assumed in this study.

Since the transport category is to be considered, only those VTOL systems which retain a basically horizontal position in take-off and landing, as well as in forward flight, will be evaluated.

Most Promising Systems

There are many VTOL systems which can lead to the configuration which will fulfill the requirement of fuselage attitude and controlled hovering flight of a few minutes. However, a broad parametric study, conducted by Vertol Aircraft Corporation in 1955–1956 under a contract with the Office of Naval Research and the Army Transportation Corps, indicated that for the transport mission requiring cruising speeds of 300 m.p.h. or more, having a radius of action of several hundred miles, and operating only a few minutes in hovering the following six systems appeared to be the most promising (Fig. 1).

Fig. 1. Six promising VTOL systems.

(1) *Tilt-Wing Propeller*

The tilt-wing aircraft whose basic concept has been pioneered by the NACA[2, 3] will, for brevity, be referred to as the tilt-wing throughout the text.

(2) *Deflected Slipstream*

The deflected slipstream (also called vectored lift) VTOL concept derives its vertical lift from the propeller slipstream which is deflected through large angles by means of special flaps and or vanes.[4–7]

(3) *Tilting Ducted Propellers*

This concept is based on shrouded ducted propellers[8–10] which can be tilted through an angle of approximately 90°, providing both vertical thrust in hovering and propelling force in forward flight.[11, 12]

(4) *Hover-Jet*

Aircraft employing direct thrust of turbojet engines for hovering and near hovering flight (Bell Aircraft tilting jet engines and the Rolls-Royce Flying Bedstead). This VTOL system is referred to as the hover-jet plane.

This work was revised by the authors and condensed from the paper of the same title presented at the VTOL-STOL Aircraft Session, IAS 25th Annual Meeting, N.Y., Jan 28–31, 1957. The original paper is still available as IAS Preprint No. 724.

The authors are Chief of Research and Development and Chief of Design Analysis, respectively. They wish to express their indebtedness to James E. Gasho and S. Dallas for their help in numerical calculations.

(5) *Vertodyne*

The Vertodyne derives its thrust in hovering and low-speed regimes from ducted fans submerged in fixed wings as originally proposed by Breguet.[13] However, whereas Breguet proposed to drive the wing-submerged ducted fans through turbine blades located on the periphery of the fans, the ducted fans of the Vertodyne are shaft driven. A hot gas generator of the turbojet type is installed either to drive the ducted fans through a power turbine or to provide thrust in forward flight through the direct discharge of hot gases as in a conventional turbojet.

(6) *Vectodyne*

This thrust-supported and -driven aircraft depends entirely on sustaining forces generated through the proper deflection of a ducted air stream both in hovering and forward flight. This whole family of aircraft originated by Dr. Lippisch as the Aerodyne[14] is discussed here under the name of Vectodyne (derived in analogy with that of vectored lift aircraft).

The previously mentioned Vertol parametric study indicated that the tilt-wing, deflected slipstream, and tilt ducted propeller aircraft are similar in their performance capabilities and structural and gross weight characteristics. Only the tilt-wing is hence considered as a typical representative of the aforementioned three concepts.

In addition to the tilt-wing, the hover-jet airplane, the Vertodyne, and the Vectodyne are discussed, while the helicopter and STOL aircraft are shown for comparison.

Basis for Comparison

The transport aircraft can be compared on the basis of (PL/W) vs. range relationship which, in turn, may be regarded as a result of two factors:

(a) The pay load to gross weight ratio for zero range $(PL/W)_0$.

(b) The average slope of the (PL/W) vs. range curve.

The first of these quantities can be expressed in terms of relative weights as follows:

$$\left(\frac{PL}{W}\right)_0 = 1 - \left[\left(\frac{W_F}{W}\right)_h + \frac{W_{PP}}{W} + \frac{W_{TR}}{W} + \frac{W_{T\&L}}{W} + \frac{W_R}{W}\right] \quad (1)$$

where $(W_F/W)_h$ is fuel required for hovering (5 min.); W_{PP}/W is power-plant installed weight; W_{TR}/W is transmission, lubrication, and fuel system weights; $W_{T\&L}/W$ is lift and thrust items—including wing, propellers, rotors, and boundary-layer control system as applicable to the various design concepts; and W_R/W is remaining items—including weight of body, alighting gear, tail surfaces, fixed equipment, crew, etc.

The slope of the relative pay load vs. distance (l) is defined as the relative weight of fuel required per 100 nautical miles of distance flown. This quantity expressed in per cent of gross weight is

$$\partial(PL/W)/\partial l \equiv \gamma = -\Delta(F/W)_{fl=100} \times 100 \quad (2)$$

where $(W_F/W)_{fl=100}$ is fuel required to fly 100 nautical miles.

Method of Presentation

A graphical presentation is based on showing, in various regimes of flight, the SHP/W values for shaft-turbine-driven aircraft and thrust to weight ratios (T/W) for jet propeller concepts. This facilitates the rapid determination of both the $(PL/W)_0$ and γ values. The significance of the terms influencing the $(PL/W)_0$ ratio is discussed first.

The relative weight of fuel required in hovering $(W_F/W)_h$ depends on three basic factors:

(a) Shaft power to weight (SHP/W) or thrust to weight (T/W) ratio required in hovering at a given altitude and temperature.

(b) Specific fuel consumption under the above conditions.

(c) Time in hovering.

Knowing the SHP/W values versus hovering density altitudes for shaft-turbine-driven aircraft, selecting a 5-min. hovering time, and assuming a specific fuel consumption constant and equal to 0.6 lb./hp.-hr., we find that the relative weight of the hovering fuel $(W_F/W)_h$ becomes proportional to the SHP/W required in this regime of flight. This allows the addition of an auxiliary scale where the $(W_F/W)_h$ values can be read directly (see Figs. 3, 4, and 6, 7, 8).

For aircraft relying on turbojet thrust for support in hovering, the $T/W = 1.0$; hence, for 5 min. of hovering at an assumed s.f.c. = 0.9 lb./lb.-hr.,

$$(W_F/W)_{hj} = 7.5 \text{ per cent}$$

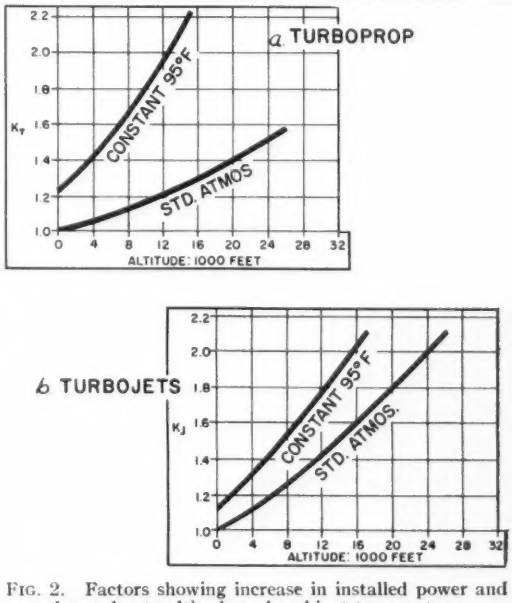

FIG. 2. Factors showing increase in installed power and thrust due to altitude and ambient temperature.

The relative weight of the installed power plant (W_{PP}/W) may be considered as proportional to the following factors:

(a) Peak power, or thrust, per pound required in all regimes of flight ($BHP/W)_{max}$ or $(T/W)_{max}$.

(b) Factor (t) representing the reserve of available power over maximum power required.

(c) Factor (K) giving the ratio of S. L. standard atmosphere power rating to that actually required at a given density altitude and temperature.

(d) Specific weight of the installed power plant based on the sea-level rating. In the present study, engine characteristics, as shown in Table 1, were assumed.

For the shaft-turbine-driven aircraft, weight of the power plant expressed in per cent of gross weight is

$$(W_{PP}/W)_t = 50(SHP/W)_{max} t_t K_t \qquad (3)$$

In hovering it is assumed that $t_h = 1.1$ while in forward flight $t_f = 1.0$.

For nonsupercharged turbines, with no provision for power recovery at nonstandard ambient temperatures, the K factor based on the present-day shaft turbines can be obtained from Fig. 2.

An auxiliary scale is provided along the ordinate axis (see Figs. 3–7) to obtain, at a glance, the relative weight of the installed power plants for $K = 1$.

In the considered hover-jet there are basically two power-plant groups—one providing thrust in hovering, another in forward flight. The relative power-plant weight expressed in per cent of gross weight is

TABLE 1
Assumed Engine Characteristics

Power Plant	Specific Installed Weight	Specific Fuel Consumption Hover	Specific Fuel Consumption Forward Flight
Turboprops	0.5 lb./*SHP*	0.6 lb./*SHP*-hr.	0.6 lb./*SHP* hr.
Hover turbojets	0.12 lb./lb.	0.9 lb./lb.-hr.	
Forward flight turbojets	0.37 lb./lb.		1.0 lb./lb.-hr.
Modified gas turbines*	0.52 lb./*SHP*	0.6 lb./*SHP*-hr.	1.07 lb./lb.-hr.

* For Vertodyne application

$$(W_{PP}/W)_j = 13.2K_{jh} + 37(T/W)_{fmax} K_{jf} \qquad (4)$$

In Eq. (4) it has been assumed that maximum thrust required in hovering is 10 per cent higher than the gross weight. The relative weight of the forward flight power plant depends on the $(T/W)_{fmax}$ in this regime, and its value can be read directly (for $K = 1.0$) from an auxiliary scale (see Fig. 5).

The relative weight of the transmission plus lubricating and fuel systems (W_{TR}/W) can be considered as proportional to the shaft power installed, and the values shown in Table 2 have been assumed. Auxiliary scales permit reading this value directly from the graphs (Figs. 3, 4, 6, and 7).

Relative weight of the lifting and thrust producing assemblies ($W_{T\&L}/W$): This item includes wings, propellers, rotors, and boundary-layer control system as applicable to the various design concepts. These items are dependent to a great extent on the size of the aircraft, design concepts, etc. Table 2 gives the approximate variation of $W_{T\&L}/W$ for various VTOL air-

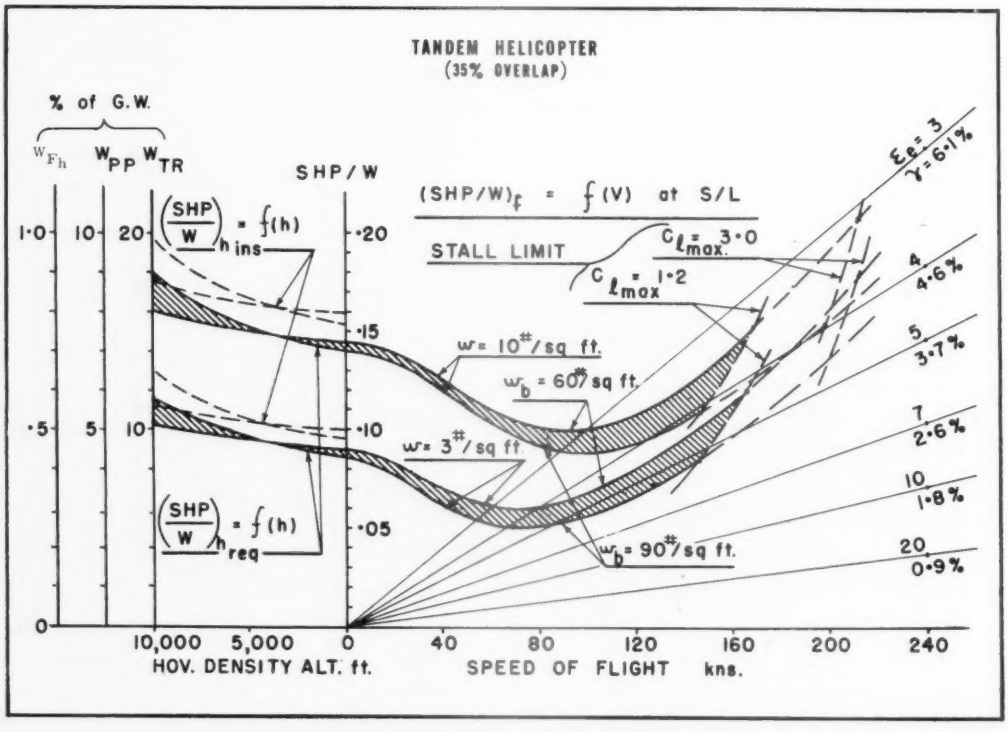

FIG. 3. Performance map for the tandem helicopter.

TABLE 2
Assumed Component Weights

Type	Helicopter	Tilt-Wing	Hover-Jet	Vertodyne	Vectodyne	STOL
W_{TR}/W	1 lb./hp.	0.3 lb./hp.	...*	0.10 lb./hp.	0.15 lb./hp.	0.25 lb./hp.
$W_{T\&L}/W$	13–16%	15–20%	9–14%	10–15%	10–20%	17–22% 20–25%
W_R/W	25%	20%	20%	20%	20%	22%

* Since there is no transmission, weight of the fuel and lubricating systems is incorporated into installed weight of turbojet engines.

craft of 50,000 to 100,000 lbs. gross weight class. It should be noted that for the STOL aircraft two sets of values are indicated for $W_{T\&L}/W$: 17–22 per cent and 20–25 per cent. The lower range has been estimated for the lower value of maximum operational lift coefficient ($C_L = 4.0$). The higher range corresponds to $C_L = 6.0$.

Relative weight of the remaining structure, crew, fixed equipment, etc. (W_R/W): For the VTOL transports of the 50,000 to 100,000 lbs. gross weight class, approximate values for W_R/W are given in Table 2. For the helicopter a 5 per cent increase has been assumed chiefly because of the heavier fuselage structure. An increase of 2 per cent for the STOL reflects primarily the heavier undercarriage.

Slope of the (PL/W) *vs. distance curve:* Eq. (2) expresses the relative weight of fuel in percentage of gross weight required to fly 100 nautical miles, and for the s.f.c. given in Table 1 it becomes for shaft-turbine-driven aircraft

$$\Delta(PL/W)_t/100\text{n.mi.} \equiv \gamma_t = (60/V)(SHP/W)_V 100 \quad (4)$$

and for jet-propelled ones

$$\Delta(PL/W)_s/100\text{n.mi.} \equiv \gamma_j = (100/V)(T/W)_V 100 \quad (5)$$

where flying speed V is in knots, and a subscript V denotes that the $(SHP/W)_V$ and $(T/W)_V$ values are taken at that speed V.

Taking advantage of Eqs. (4) and (5), we can draw a grid of lines on the SHP/W or T/W vs. V graphs which enables the immediate appraisal of the PL/W vs. range slope at various cruise speeds and flight altitudes (see Figs. 3–8).

Equivalent lift to drag ratio (ϵ_e): For jet-propelled aircraft the reciprocal of the T/W values obviously represents the lift to drag ratio ($\epsilon = L/D$). In order to facilitate a comparison of the shaft-turbine-driven aircraft with the jet-propelled ones, an equivalent lift to drag ratio (ϵ_e) based on the SHP/W values has been introduced as follows:

$$\epsilon_e = 325(SHP/W)/V \quad (6)$$

From Eq. (6) it is easy to provide within the $(SHP/W) \div V$ coordinates system a grid of constant ϵ_e lines (see Figs. 3, 4, and 6–8). Thus the values of ϵ_e at various flying speeds, altitudes, etc., can be read directly. These figures can be compared with the ϵ values read

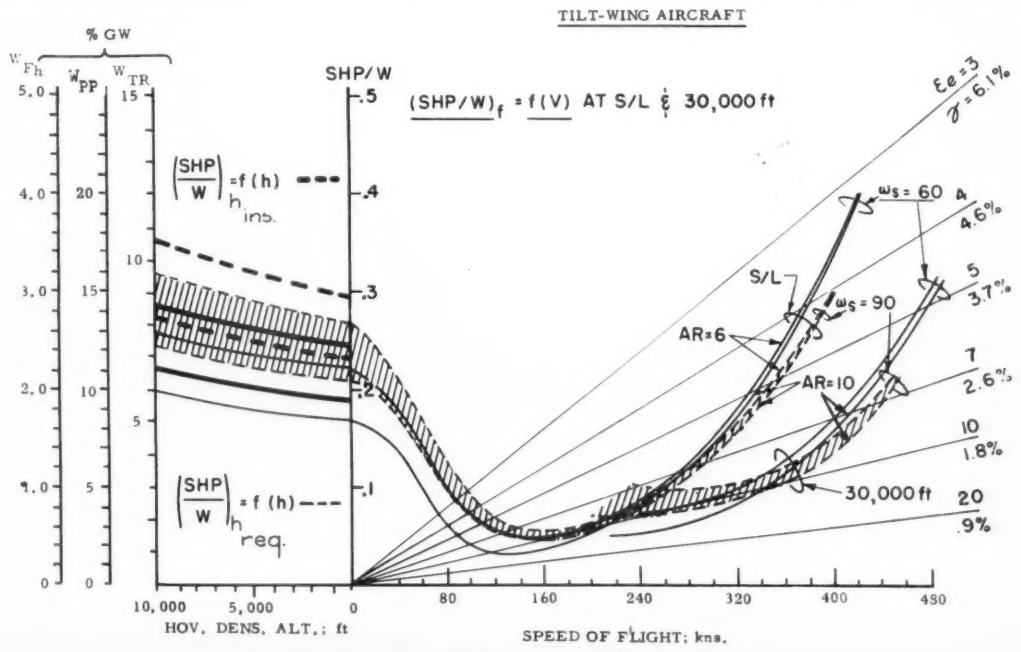

FIG. 4. Performance map for tilt-wing aircraft.

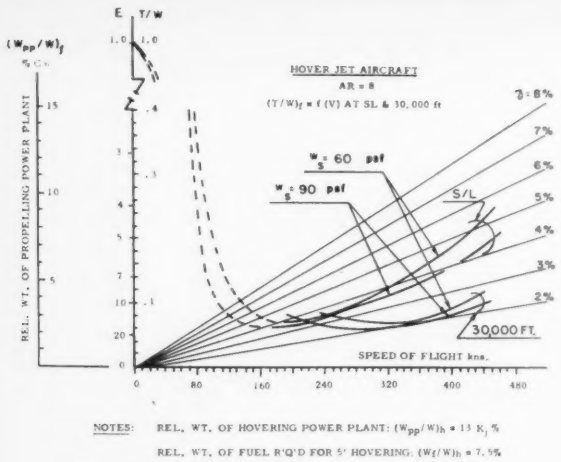
HOVER JET AIRCRAFT
AR = 8
$(T/W)_f = f(V)$ AT SL & 30,000 ft
W_s = 60 psf
W_s = 90 psf
S/L
30,000 FT.
SPEED OF FLIGHT kns.
REL. WT. OF PROPELLING POWER PLANT
$(W_{pp}/W)_f$
T/W
E
NOTES: REL. WT. OF HOVERING POWER PLANT: $(W_{pp}/W)_h$ = 13 K_j %
REL. WT. OF FUEL R'Q'D FOR 5' HOVERING: $(W_f/W)_h$ = 7.5%

FIG. 5. Performance map for hover-jet aircraft.

on an auxiliary ordinate scale of the T/W vs. V graphs of the jet-propelled aircraft (Fig. 5).

DISCUSSION OF VTOL AND STOL SYSTEMS

(*A*) *The Helicopter*

TABLE 3
Assumed Design Parameters of the Helicopter

Disc loading, psf	3		10	
Blade loading, psf	60	90	60	90
Tip speed @ c_l = 1.2	655	695	655	695
fps @ c_l = 3.0	590	615	590	615
Equivalent flat plate area loading, psf	1,000			

The power required relationships, both in hovering and in forward flight, based on the above values are shown in Fig. 3. This figure indicates that an increase of the retreating blade lift coefficient from the generally accepted present value of $c_{l_{max}}$ = 1.2 to $c_{l_{max}}$ = 3.0 may result in pushing the combined stall-compressibility limit to 200 knots or more.

But these gains in V_{max} will probably not improve the optimum values of γ which, compared with either VTOL or STOL aircraft at sea level, are rather low (see Figs. 3 and 10) and may compare only with jet-propelled aircraft flying at S/L.

The commonly accepted opinion that the helicopter is the best hovering vehicle is verified by examining the left side of Fig. 3. In spite of the fact that these advantages are less striking at the selected time of only 5 min. in hovering, the helicopter with the lower disc loading shows the best $(PL/W)_0$ of all considered VTOL aircraft (see Fig. 11). At longer times required in hovering or near hovering flight, this superiority of the helicopter will obviously become more pronounced.

Because of the superior hovering and low-speed performance, the helicopter will probably remain for a long time an optimum VTOL aircraft for short-range operations where frequent stops are required and consequently considerable time is spent in hovering or near hovering flight.

(*B*) *Tilt-Wing*

TABLE 4
Assumed Design Parameters of the Tilt-Wing

Wing loading, w_s, psf	60		90	
Aspect ratio	6	10	6	10
No. of propellers	4			
Propeller diameter	1/4 (wing span)			
Equivalent flat plate area loading, w_f, psf	4,200			

The selected design parameters result in the power required per pound of gross weight shown in Fig. 4. The

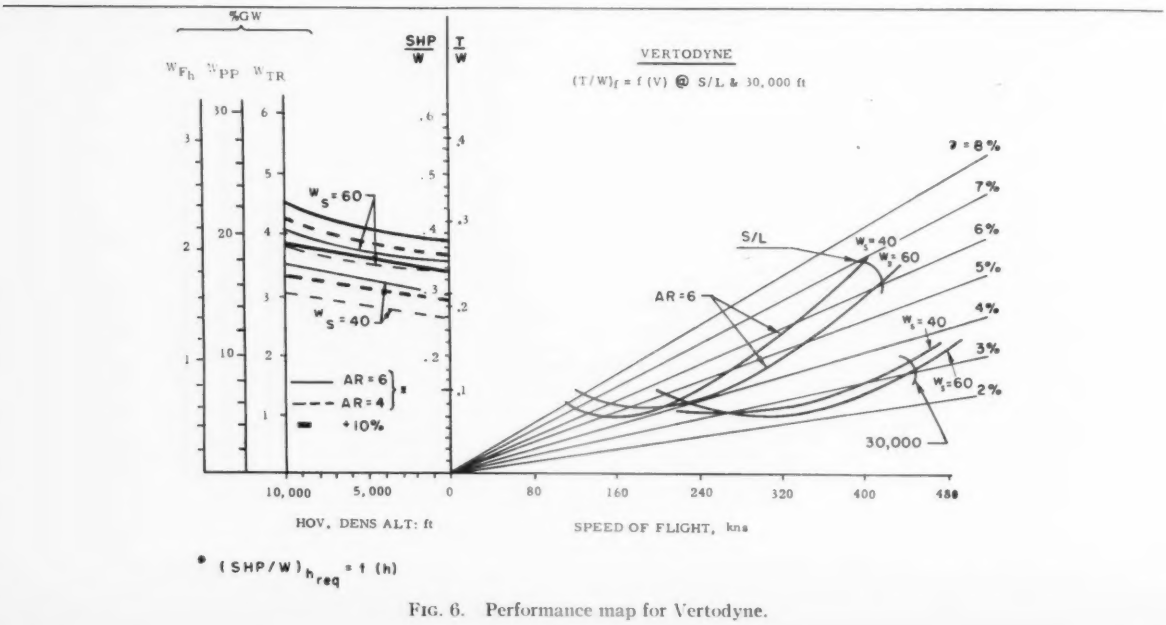

FIG. 6. Performance map for Vertodyne.

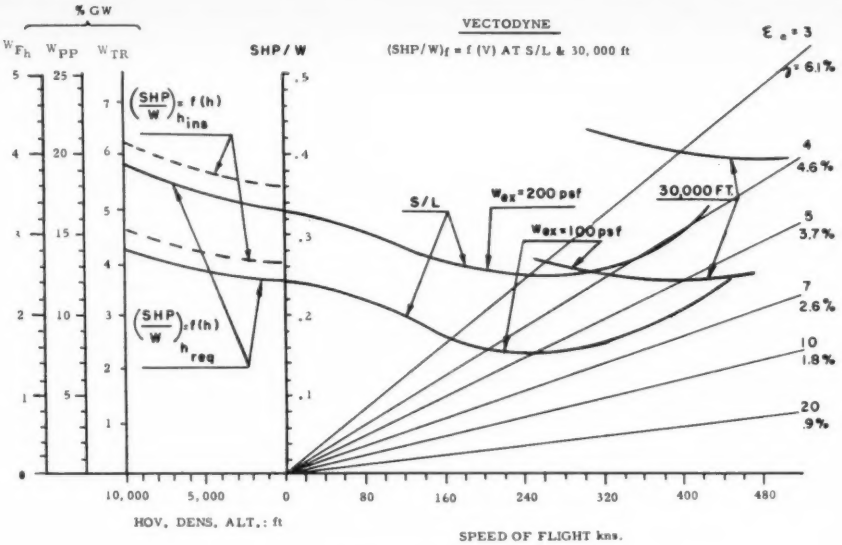

FIG. 7. Performance map for Vectodyne.

improved speed and range capabilities (indicated by the γ values) over the helicopter can easily be noticed in Fig. 4.

A combined examination of Figs. 4 and 11 indicates that, as far as the overall performance is concerned, the lower wing loading of 60 lbs./sq.ft. is more beneficial since under the assumptions of Table 4 this leads to a lower propeller disc loading as well. Fig. 11 also indicates that, as for all other VTOL aircraft, the pay load at zero range will diminish considerably with operational altitudes and temperature in hovering as long as the engines lose power as shown in Fig. 2.

In general the $(PL/W)_0$ values of the tilt-wing aircraft incorporating a lower wing loading (60 lbs./sq.ft.), and hence lower propeller disc loading as well, are quite good and, for the assumed time in hovering (5 min.), only slightly inferior to those of the helicopter; while in the PL/W vs. range capabilities (γ values), the tilt-wing shows a definite superiority both at low- and high-altitude flights even at high cruise speeds of approximately 300 to 360 knots.

The tilt-wing is thus considered one of the best VTOL concepts for transport aircraft for cruise speeds of approximately 300 to 360 knots.*

(C) *Hover-Jet*

The hover-jet aircraft may be considered as a conventional jet-propelled transport aircraft to which special hovering jet engines and special controls for this regime of flight have been added. In forward flight, hence, the γ values should be similar to any other jet transport, and obviously a high cruising altitude should be beneficial.

* The vectored lift and tilting ducted propeller would probably be comparable to the tilt-wing.

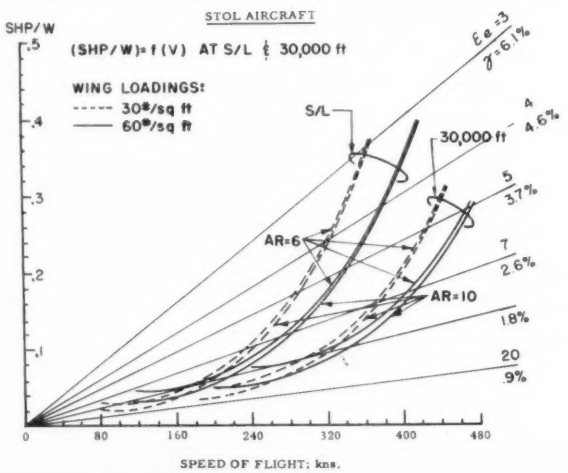

FIG. 8. Performance map for STOL aircraft.

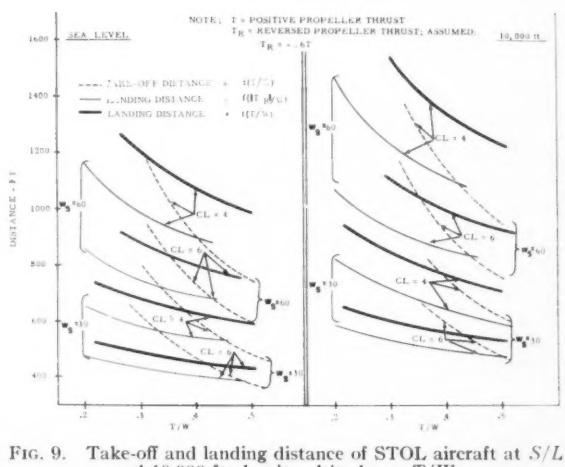

FIG. 9. Take-off and landing distance of STOL aircraft at S/L and 10,000 ft. density altitude vs. T/W.

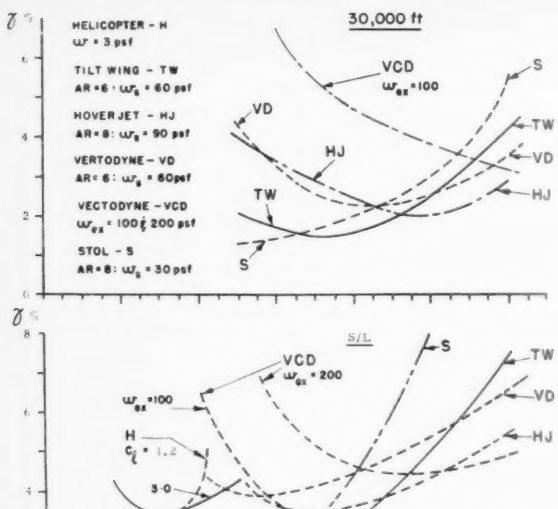

FIG. 10. Fuel required per 100 nautical miles, per cent gross weight (γ) vs. flying speed at S/L and 30,000 ft.

In view of the basic similarity of the hovering jet to the whole family of jet transport aircraft, only one aspect ratio ($AR = 8$) and two wing loadings ($w_s = 60$ and 90 lbs./sq.ft.) were considered. The equivalent flat plate area loading (excluding the wing and tail surfaces) was taken as $w_f = 5{,}500$ lbs./sq.ft.

From Figs. 5 and 10 it can readily be seen that in the high-speed range of approximately 460 to 480 knots and in the high altitudes the γ values are superior to other concepts considered. The pay load at zero range (see Fig. 11) is obviously much lower than can be expected of conventional jet transports. Figs. 10 and 11 indicate that the higher wing loading results in better transport capabilities [both γ and $(PL/W)_0$].

The hover-jet is an interesting VTOL transport concept for cruise speeds higher than 450 knots. However, the competitive position of this aircraft is largely dependent upon the time required in hovering and the development of extremely lightweight turbojet engines for vertical thrust.

(D) *Vertodyne*

In forward flight the Vertodyne is a jet-propelled aircraft, hence its characteristics should be similar in general to those of any other jet transport aircraft and to the hover-jet in particular. However, a more complicated ducting arrangement between the jet exit nozzle and the gas generator may result in a higher s.f.c. (7 per cent higher in forward flight has been assumed).

Since in high-speed forward flight aspect ratio is of lesser importance, only one value ($AR = 6$) was assumed for the forward flight study. However, two wing loading values ($w_s = 40$ and 60 lbs./sq.ft.) were considered. The equivalent flat plate area loading was taken as $w_f = 4{,}600$ lbs./sq.ft.

Although in a high-speed flight the aspect ratio value is less important, it becomes a significant design parameter as far as hovering flight characteristics are concerned. In the considered design concept (see Fig. 1) the aspect ratio influences the ratio of the ducted fan disc loading to the wing loading. Hence in the hovering study, an additional aspect ratio of 4 was added.

A glance at Figs. 6 and 10 will indicate that the forward flight relationships of the Vertodyne are similar to those of the hover-jet. In hovering, however, the thrust loading of the vertical thrust generator is lower than that of the hover-jet, which immediately reflects in a lower amount of hovering fuel required. A further examination of Fig. 11 reveals that, as far as hovering is concerned, a combination of a low aspect ratio and low wing loading is beneficial because it leads to a lower fan loading.* This more efficient use of fuel energy in hovering in the Vertodyne makes its $(PL/W)_0$ about 10 per cent at sea level and 5 per cent at 6,000 ft., 95°F. better than that of the hover-jet.

In conclusion, the Vertodyne should be considered best suited for missions requiring cruise speeds of 450 knots and higher in combination with hovering durations of 5 min. or even slightly more.

(E) *Vectodyne*

Since the Vectodyne represents a new design concept lacking in any statistical material, estimates of structural weights may vary within considerable limits. However, in spite of the uncertainty of structural data, the indications resulting from the aerodynamic considerations should be quite valuable.

In the present study two jet exit area loadings of $w_{ex} = 100$ and 200 lbs./sq.ft. were selected, and the equivalent flat plate area loading of $w_f = 5{,}000$ lbs./sq.ft. was assumed.

It can be readily seen from Fig. 7 that relatively low jet exit area loading is essential for both forward flight and hovering performance. Fig. 10 clearly indicates that the Vectodyne shows its full advantage at high speeds as far as fuel consumption is concerned. Therefore a high degree of aerodynamic cleanliness and delaying of compressibility effects becomes important. For the $(PL/W)_0$ values (Fig. 11), the exit area loading is of prime importance, especially at high altitudes and temperatures.

It may be concluded that from a performance point of view the Vectodyne represents a VTOL system which should be especially attractive for transport aircraft required to operate at relatively low altitudes and at cruising speeds of 450–480 knots or higher.

* For other ducted fan - wing configurations, this trend may be different.

(F) *STOL Aircraft*

TABLE 5
Design Parameters Assumed for STOL Aircraft

Wing loading, w_s, psf	30		60	
Aspect ratio	6	10	6	10
Operating maximum lift coefficient in landing and take-off	4 & 6	4 & 6	4 & 6	4 & 6
Equivalent flat plate area loading (excluding wing and empennage), w_f, psf	4,200			

Assuming the above design parameter values, the shaft horsepower required in forward flight was determined and the take-off and landing distances calculated at sea level and 10,000 ft. density altitude (approximately 6,000 ft. pressure altitude and 95°F. temperatures).

It can be seen from Fig. 8 that, in general, the high forward speed characteristics of the STOL aircraft are very similar to those of the tilt-wing.

Fig. 9 indicates that, for the assumed operational maximum lift coefficients, it will be difficult to realize the 600 ft. landing distances at 6,000 ft. altitude on 95°F. for an aircraft of 60 lbs./sq.ft. wing loading. The $(PL/W)_0$ is shown, hence, for a wing loading of 30 lbs/sq.ft. only.

It has been assumed that propellers are mechanically interconnected to prevent thrust assymmetry in the case of take-off engine failure. The weight penalty resulting from this can be seen in Fig. 11. It is possible to visualize a multiengined configuration (four or more engines) where either the engines are grouped in pairs or distributed along the wing span so that the assymmetry resulting from one engine failure could be balanced by a control displacement. However, even in this case, the full weight gains resulting from the elimination of interconnecting transmissions will not be realized since larger control surfaces, etc., will be required.

At higher cruising speeds, both at sea level and at 30,000 ft., the γ values of the STOL are obviously quite similar to those of the tilt-wing (Fig. 10).

In the estimate of $(PL/W)_0$ (Fig. 11), provisions were made for fuel required for take-off, wave-off, etc. Installed engine power was based on the maximum forward thrust to weight ratio (T/W) as shown in Fig. 9.

Upon examining Figs. 10 and 11 we can conclude that the STOL aircraft (operational $C_{L_{max}} = 4$ to 6) should have no appreciable gross weight advantage over a VTOL tilt-wing type designed to the same mission.

CONCLUSIONS

It may be stated in conclusion that each VTOL system analyzed may be particularly suitable as a transport depending on the mission requirements and especially on such factors as cruise speed and altitude, hovering duration, etc. However, the present analysis was based on performance capabilities only. There may be structural and operational problems which may change this comparative evaluation.

The final solution to these problems and many others can be determined only through actual flying experience. Fig. 12 clearly indicates that any attempt to secure the answers to these basic problems with full-scale VTOL transport (in say 50,000 lbs. gross weight class) would be costly and time consuming. The logical approach appears through the small test aircraft where only at a fraction of the cost and time required for full-

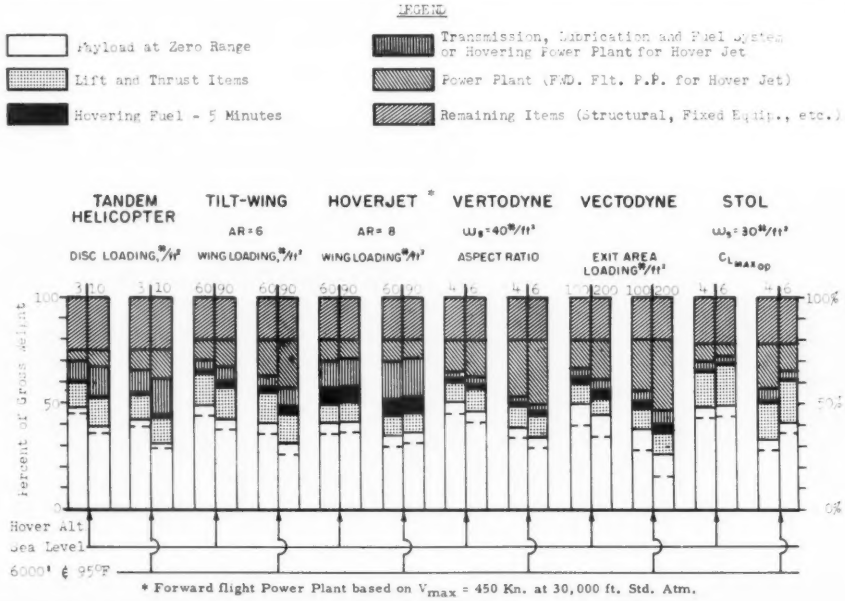

FIG. 11. Pay-load capabilities at zero range of VTOL and STOL transports.

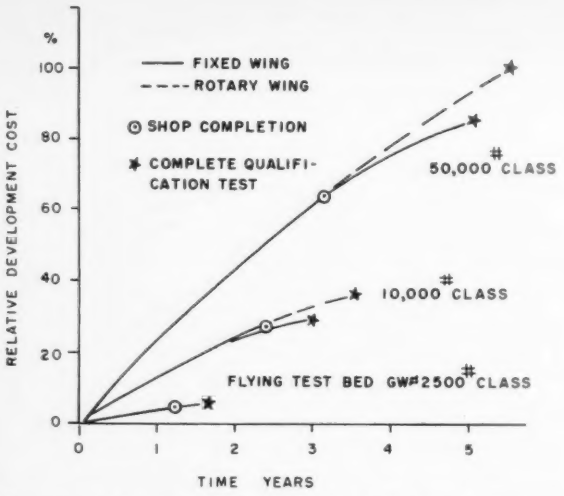

FIG. 12. Relative development cost vs. time for various gross-weight-class aircraft.

scale transports the necessary basic answers may be obtained.

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Effects of Inlet Pressure and Temperature Transients (Continued from page 59)

CONCLUSIONS

Experiments have shown that rapid transients in inlet pressure or temperature may cause compressor stall in modern turbojet engines. The stall leads to excessive vibration, very high turbine temperatures, and quite frequently, to combustor blowout. It is, therefore, an important engine operating limit. Experiments also show that the stall limits of the engine under these conditions are different than for quasi-steady conditions.

An explanation of the phenomena occurring and a quantitative prediction of the stall limits is possible from a simple analysis based on a dynamical model of the engine. The results showed that for small groups of compressor stages the steady-state performance and stall limits are valid over a wide frequency range, and that dynamic effects are those given by the transient response of gas volumes corresponding to the volumes of the stage groups and the combustor.

As an example of the application of the methods of analysis, the stall limit of a typical engine in the presence of diffuser buzz is computed, and it is shown that stall occurs in the buzz amplitude frequency range. In addition it is shown that a quasi-steady analysis of the effect of ramps in inlet temperature will result in large errors in predicted engine stall limits, and that these errors may be eliminated by the use of the transient analysis proposed herein.

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Airplane Design Implications of the Inertia Coupling Problem

The purpose of this paper is to generalize some of the more important aircraft design implications resulting from consideration of high rolling rate and large amplitude roll maneuvers.

Introduction

One of the most significant new stability and control problems is that which results from inertia coupling during roll maneuvers. This problem comes about in large amplitude roll maneuvers and can result in sufficiently large pitch and yaw excursions to pose a primary flight safety problem. The problem is of particular concern in the design of fighter and interceptor aircraft, where high rolling rate and large amplitude roll maneuvers are critically required in the basic tactical employment of the weapon.

It is the purpose of this paper to generalize, insofar as possible, some of the more important aircraft design implications resulting from consideration of this type of maneuver. The considerations presented are derived from analytical studies of the equations of motion of typical high-speed aircraft configurations.

Early indications of the possibility of instability during roll maneuvers of aircraft and missile configurations were presented by W. H. Phillips of the NACA Langley Laboratory.[1] More detailed theoretical investigations have since been reported by other authors, but the conclusions reached by Phillips remain valid and provide a simple basis for design considerations. A brief review of the results of Phillips' analysis is included here to introduce the significant parameters and to provide a basis for the design considerations to be discussed.

On the basis of a number of simplifying assumptions, Phillips reduced the equations of motion to a linear system permitting a general solution of the problem in terms of the natural frequencies in pitch and yaw, ω_θ and ω_ψ. These quantities are related directly to the longitudinal and directional static stability margins of the configuration. For airplanes with low inertia in roll the results show the possible existence of an area of instability for a given configuration rolling at a rate between the natural frequency in pitch and the natural frequency in yaw. The extent of this unstable region is a function of the existing damping. Rolling rates either above or below these natural frequencies lie in stable regions. It is implied that for the special case of ω_θ equal to ω_ψ, the presence of a small amount of damping is sufficient to provide stability at all roll rates.

These results from Phillips' analysis were determined from consideration of aircraft configurations rolling at fixed rate. Certain general conclusions may be drawn from the results of Phillips indicating the most critical areas for consideration of the inertia coupling problem. Nevertheless determination of the actual roll rates to be experienced by aircraft configurations over a wide range of speeds, altitudes, and entry attitudes requires application of 5 degree of freedom response calculations. The remainder of this paper presents results of design significance drawn from Phillips' analysis together with the results of dynamic studies of typical high-speed aircraft configurations.

Typical Aircraft Configuration Characteristics

In the preliminary design consideration of a new aircraft, attention is focused in sequence upon each element of the configuration in order to accomplish the design objective. The choice of directional and longitudinal static stability levels in conjunction with allowable center of gravity limits is of extreme importance and must be based upon consideration of the complete flight spectrum.

Several typical aircraft configurations have been examined to establish the variations of longitudinal and directional stability over a wide Mach Number range. These variations in directional and longitudinal

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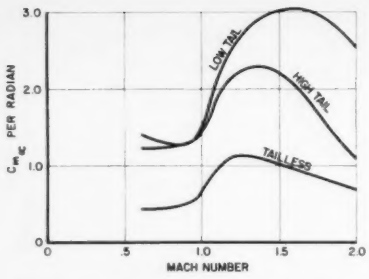

FIG. 1. Typical pitch stability variation with Mach Number.

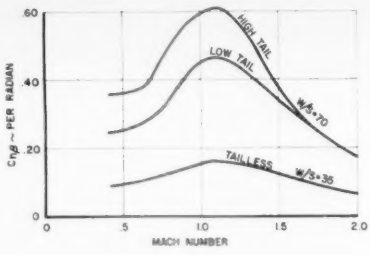

FIG. 2. Typical directional stability variation with Mach Number.

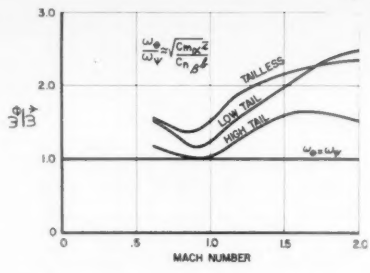

FIG. 3. Variation of natural frequency ratio with Mach Number.

stability have been assessed in order to establish the characteristics of typical configurations for consideration from the inertia roll coupling standpoint. Fig. 1 presents typical variations of the longitudinal stability parameter, C_{M_α}, with Mach Number for low and high positions of a horizontal tail of a conventional high-speed design as well as a tailless design. The lower values of the longitudinal stability parameter for the tailless configuration reflect the normally larger wing area and aerodynamic chord lengths associated with such arrangements.

Preliminary design attention must be directed to the determination of the variation of longitudinal stability with Mach Number for the particular configuration of interest in order to establish the most critical flight speed. For many current aircraft of widely varying configurations, the critical speed for selection of longitudinal stability design parameters is in the vicinity of 0.9 Mach Number. It is in this region that many configurations exhibit the lowest levels of static longitudinal stability. Selection of allowable aft center of gravity limits together with horizontal tail size for tailed configurations is made at this point. Once selected at the critical speed, the variations in longitudinal stability parameter over the Mach Number range are inherently determined by the configuration as indicated in Fig. 1.

Similar design considerations apply to the choice of aircraft directional stability level. For all types capable of flight at high supersonic speeds, the critical directional stability design point coincides with the maximum design speed. The inherent reduction of lift curve slope of the vertical tail together with the constant instability of the aircraft fuselage result in this condition. Preliminary design considerations are directed at the selection of a vertical tail configuration to give the desired restoring moment at this flight condition. Substantial variations of the directional stability parameter, $C_{n\beta}$, occur with Mach Number for all aircraft configurations depending upon the specific arrangement. Fig. 2 presents typical variations of the directional stability parameter for the high-speed aircraft configurations previously considered from the longitudinal standpoint using representative wing loadings.

Variation of the ratio of natural frequency in pitch, ω_ϕ, to natural frequency in yaw, ω_ψ, is presented in Fig. 3 for the three aircraft configurations whose stability variations were shown in Figs. 1 and 2. The inherent aerodynamic variations of longitudinal and directional stability parameters result in wide variations in the ratios of natural frequencies over the flight speed range.

It is concluded from Fig. 3 that all aircraft configurations designed for performance over a wide range of Mach Numbers from subsonic to high supersonic speeds will be characterized by large variations in the ratio of pitch to yaw natural frequencies. Although it is possible to design equal values of pitch and yaw natural frequencies at one Mach Number in order to obtain the most favorable response in roll maneuvers as indicated by Phillips, frequency ratio differences as indicated in Fig. 3 will occur at other Mach Numbers. Thus, operation of such aircraft in roll maneuvers under conditions in which the results of reference 1 indicate increased probability of instability is unavoidable. It is further concluded from Fig. 3 that, for many configurations of practical significance, the natural frequency in yaw will be less than the natural frequency in pitch. The natural frequency in yaw for such configurations will thus establish the rolling rates likely to lead to instability.

Fig. 4 presents the typical variation of yaw natural frequency with altitude as compared to its value at sea level. This variation reflects the normal reduction in air density with altitude for flight at a constant Mach Number. Reduction of the critical yaw natural frequency with altitude shows that an altitude will be reached for any aircraft at which the design rolling rate will result in a roll frequency equal to or greater than the yaw natural frequency.

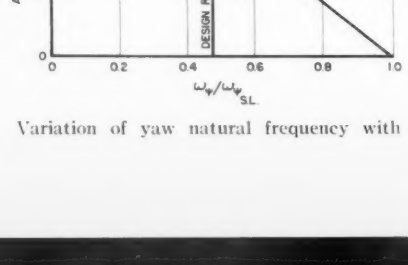

FIG. 4. Variation of yaw natural frequency with altitude

It is apparent from the considerations of Figs. 3 and 4 that possibility of instability in roll maneuvers and aircraft design attention to eliminate such instability must increase as the speed and altitude of flight increase. The design levels of roll performance to be obtained in high-speed and high-altitude flight must be examined carefully with respect to the design penalties paid to achieve such roll performance levels. The significance of roll inertia coupling as a high-speed, high-altitude design problem is thus established.

Analysis and Design Implications

Accurate determination of airplane response resulting from rapid deflection of the roll control requires consideration of 5 degrees of freedom of the aircraft. Forward speed variations need not be considered because of the brief duration of the maneuver. The mathematical representation in 5 degrees of freedom is established from the standard equations of motion and a set of Eulerian transfer equations to locate the disturbed axes in space during the large amplitude maneuver. To determine accurately the aircraft response in such a mathematical model, the nonlinearities introduced by the axis transfer and the nonlinearities of all of the important aerodynamic derivatives must be included. Some 25 total aerodynamic inputs, including the nonlinear variation of important derivatives with angle of attack, must be combined in the set of nonlinear differential equations. Solution of these equations is obtained by either analog or digital computing equipment. Time histories of typical maneuvers studied by this means are presented in the remainder of this paper to illustrate the significant design implications involved.

One of the most important considerations determining the roll rate developed in an actual dynamic roll response maneuver results from the aircraft roll entry conditions. This point is illustrated by Figs. 5 and 6 which present time histories of aileron hardover roll maneuvers of a typical aircraft configuration at a speed of Mach 2.0 and an altitude of 40,000 ft. Fig. 5 shows a time history of a rolling maneuver at these flight conditions in which the roll is rapidly entered from a 5.0g steady turn. From this entry condition initial unfavorable sideslip develops. This unfavorable sideslip through the normal positive dihedral effect provides a rolling moment opposite to that provided by the ailerons resulting in reduced rolling rate. Such sense of sideslip is designated "inhibiting" in this paper. Rolling rate does not reach a value as high as the natural frequency in yaw shown in Fig. 5 with the result that the maneuver is stable and the airplane responds rapidly to aileron reversal. Sideslip angle and normal load factor variations are small throughout, but the substantial reduction in roll rate may be unacceptable. The same maneuver performed in the presence of zero dihedral effect is also shown in Fig. 5. In this case the inhibiting sideslip does not reduce roll performance, and the excursions in sideslip and load factor remain at moderate levels.

In Fig. 6 the roll is initiated at the same flight conditions as Fig. 5 from a symmetrical pushover to a normal load factor of zero g. In this condition favorable sideslip is immediately produced. This favorable sideslip through normal positive dihedral effect produces a rolling moment in the same direction as the ailerons and augments the roll rate to exceed both the critical frequencies in pitch and yaw. This sense of sideslip is designated "augmenting" in this paper. When the ailerons are reversed at the completion of the first revolution of this roll, the roll rate initially responds but does not return to zero when the roll rate falls into the unstable region between ω_θ and ω_ψ. Throughout the maneuver, the sideslip angle and normal load factor continue to increase. In effect a condition of autorotation in roll is established wherein the rolling rate is not reduced to zero though the ailerons are set against the roll. When the design lateral stability level is reduced to zero in Fig. 6, the sideslip response does not generate high roll rates and the sideslip and normal load factor excursions are reduced to acceptable values.

These results are summarized for the subject flight condition in Fig. 7 where the maximum sideslip angle developed and the effective rolling rate are shown as a function of entry attitude. The inherent variation of sideslip angle with entry condition exists irrespective of the design level of lateral stability. This response is generated primarily as a result of the inclination of the longitudinal mass axis with respect to the flight direction. The effect of roll entry attitude is most pronounced in supersonic configurations where low aspect ratio wing design and supersonic speeds give low lift curve slope values which results in large variations in entry attitude as a function of normal load factor.

The significant effect of design lateral stability level on roll performance and stability is evident from the right-hand portion of Fig. 7. The presence of large dihedral effect results in substantial reductions of roll performance under conditions of increased entry attitude, while producing sufficiently large roll rates as to result in unsatisfactory coupled maneuvers for low entry attitude conditions. Reduction of design lateral stability to a negligible value yields approximately uniform roll performance over the full range of entry attitudes, while maintaining freedom from unstable or large excursion inertia coupled maneuvers.

The results of the foregoing discussion indicate the desirability of maintaining low design lateral stability levels for high-speed configuration aircraft. The lowest level of lateral stability yielding acceptable normal sideslip response to the pilot provides a minimum variation of roll performance over the full range of entry attitudes thus maximizing roll performance at high g conditions and minimizing the possibility of roll coupling at low g conditions.

The simplified considerations of reference 1 indicate that directional and longitudinal stability levels play an important role in dynamic roll response. Fig. 8 presents confirmation of this fact by means of a series

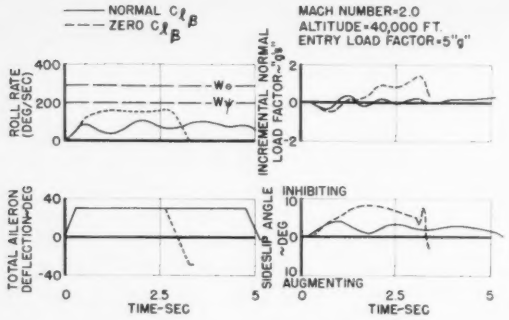

FIG. 5. Effect of airplane dihedral in rolling maneuvers—high entry load factor.

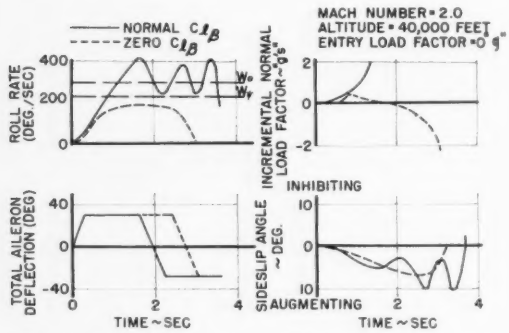

FIG. 6. Effect of airplane dihedral in rolling maneuvers—low entry load factor.

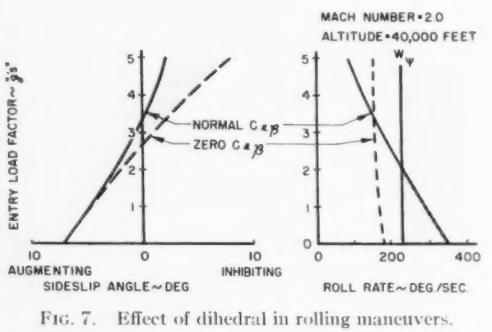

FIG. 7. Effect of dihedral in rolling maneuvers.

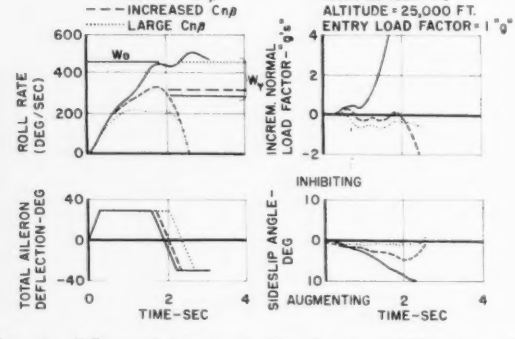

FIG. 8. Effect of increased directional stability in rolling maneuvers.

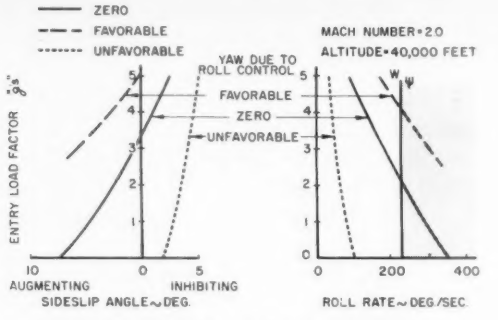

FIG. 9. Effect of yaw due to roll control.

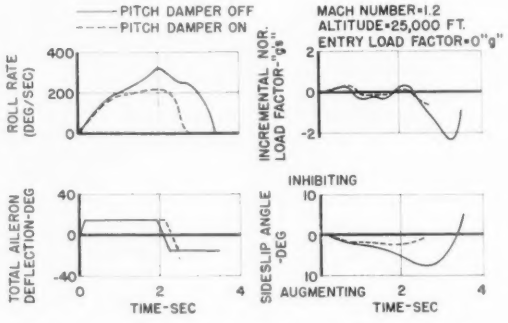

FIG. 10. Effect of artificial damping at low altitude.

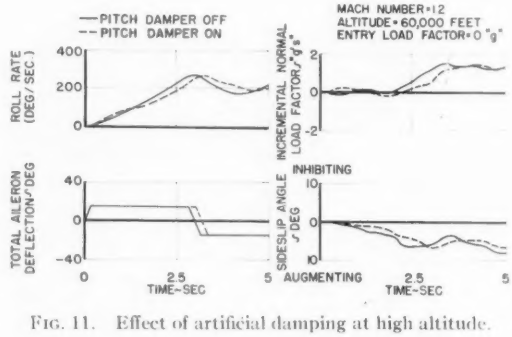

FIG. 11. Effect of artificial damping at high altitude.

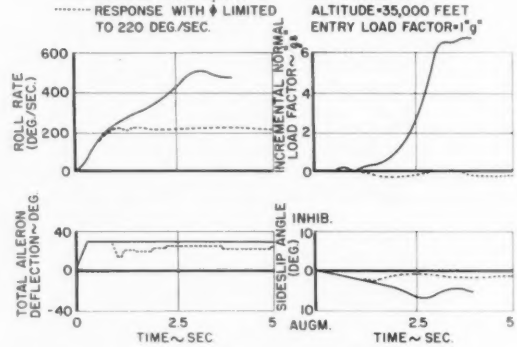

FIG. 12. Effect of roll rate limiting.

of three time histories in which the basic directional stability level undergoes substantial modification.

Fig. 8 presents time histories for roll maneuvers entered from lg flight at a Mach Number of 1.6 and a flight altitude of 25,000 ft. for a typical high-speed aircraft configuration. In the basic case, large augmenting sideslip angles develop, and through the positive dihedral effect very high roll rates result. The excursions in both normal load factor and sideslip are totally unacceptable. For this configuration the natural frequency in pitch, ω_θ, is approximately 460° per sec. while the natural frequency in yaw, ω_ψ, is 290° per sec. Roll rate in this maneuver exceeds both ω_θ and ω_ψ.

Directional stability of the configuration under consideration is increased by addition of vertical tail surface in two steps increasing the natural frequency in yaw to 320° per sec. and 460° per sec. Rolling rate is lessened by the increased directional stability as the sideslip angles experienced are substantially reduced. The first increase in directional stability brings the peak roll rate just in excess of natural frequency of 320° per sec., and the response is seen to be acceptable. A further large increase in directional stability brings the rolling rate to less than half of the increased natural frequency of 460° per sec. and results in only insignificant excursions in sideslip and normal load factor.

The general results of Fig. 8 are in agreement with the conclusions of reference 1, although the dual nature of the aircraft design problem is revealed. The rolling rate produced is a function of the design changes made to modify the natural frequency values, and thus for many flight conditions only minor stability modifications will result in substantial improvement of dynamic response. The intermediate case of Fig. 8 shows that penetration of the possibly unstable region between ω_ψ and ω_θ can be made without necessarily incurring unacceptably unstable aircraft response, particularly when the practical airplane design conditions of a limited number of revolutions in roll are considered. This conclusion has been verified by other cases not shown in which substantial penetrations of the theoretically unstable region can be made without difficulty. Nevertheless the basic levels of directional and longitudinal stability remain of the utmost importance if satisfactory dynamic response is to be obtained in roll maneuvers.

In the area of flight control design and selection, considerations of the inertia coupling roll problem appear to have the most significance with respect to the choice of lateral control. The direct influence of the design roll power level is apparent from the considerations of reference 1 and the material presented in previous sections of this paper.

The powerful effect of the yaw produced by lateral control deflection is shown in Fig. 9. Fig. 9 presents sideslip and roll rate results for a range of entry conditions for a typical high-speed aircraft configuration at Mach 2.0 and an altitude of 40,000 ft. In this figure, yaw due to lateral control deflection is varied both in the unfavorable and the favorable directions from zero. The sideslip and roll rate effect produced by such variations in yaw due to lateral control are seen to be large. Favorable yaw due to lateral control deflection increases roll performance at high g entry conditions but also increases the possibility of inertia coupling for low g entry conditions. Unfavorable yaw due to lateral control minimizes the possibility of inertia coupling but leads to large reductions in roll performance at high g conditions where roll rates may already be low. For this range of configurations the design problem is seen to be the choice of a lateral control configuration possessing yaw characteristics balanced between the low roll rates produced with large unfavorable yaw and the instabilities produced by substantial favorable yaw.

Another preliminary design implication of interest is that which results from the ability of artificial damping devices to provide satisfactory response in roll maneuvers of high-speed configurations. Such artificial damping devices have become characteristic features of all high-speed aircraft designs in order to obtain satisfactory normal flying characteristics over the flight speed and altitude spectrum. Such damping devices affect the response in roll maneuvers also, and therefore may be utilized under some conditions to provide satisfactory response.

Fig. 10 presents typical time histories of roll maneuvers at a flight speed of Mach 1.2, an altitude of 25,000 ft., and an entry condition of a zero g pushover. Comparison of the time histories with and without artificial pitch damping in this figure show the significant effect of the pitch damper on the maneuver. The augmenting sideslip excursion is substantially reduced with attendant reduction in peak rolling rate for this case wherein normal positive dihedral effect existed. The peak rolling rate is reduced by pitch damping but remains of sufficient magnitude to be fully satisfactory from a roll performance standpoint. The reduction of excursions in sideslip and incremental normal load factor are large, resulting in mild behavior throughout the time history. The reduction in sideslip excursion greatly reduces vertical tail loads, thus implying that artificial damping devices can be employed from the design standpoint to maintain loads within satisfactory levels.

Fig. 11 presents time histories for maneuvers entered from the same speed and entry attitude conditions but at an increased altitude. The basic condition in Fig. 11 without artificial damping is of the type which becomes autorotational upon aileron reversal. Application of a high level of pitch damping is shown not to affect the response appreciably. Studies similar to that summarized in Fig. 11 on artificial pitch and yaw damping have led to the general design conclusion that such artificial damping can have marked beneficial effects for flight in conditions where the aerodynamic forces are large, relative to inertial forces. Such conditions are normally met for flight at the lower altitudes. At an increased altitude, the inertia forces

become large with respect to the aerodynamic forces, and the benefits derived from the artificial damping sources are reduced.

Many detailed considerations outside the scope of this paper are involved in the utilization of artificial damping devices for the control of response in roll maneuvers. Typical of these problems are considerations of authority limitations from a flight safety standpoint and such normal damper design features as signal washout. Normal damper design practice and flight safety considerations may conflict with the requirements to achieve maximum damper effect upon roll maneuvers. Complete detailed representations of damper operating characteristics entailing an accurate statement of the damper transfer function and authority limitations must be programed into the 5 degree of freedom computations to make a correct evaluation.

Consideration of the basic nature of the inertial coupling roll problem leads to the design possibility that satisfactory flight performance could be obtained by providing a type of lateral control in which the rate of roll is limited to a selected level by an automatic control device. The device would have the authority to reduce lateral control deflection even though the pilot would continue to call for full control deflection.

To illustrate the effectiveness and characteristics of such a roll rate limiting control, two dynamic responses for roll maneuvers at a speed of Mach 1.5, an altitude of 35,000 ft., and an entry condition of 1*g* are shown in Fig. 12. In the case without roll rate limitation, the lateral control is fully deflected and held through several revolutions of roll. The sideslip developed is of the augmenting sense, and the roll rate grows to extreme values. The resulting normal load factor and sideslip excursions are large and unacceptable.

With the inclusion of an automatic roll rate limiting device, the initial pilot input of lateral control deflection remains unaltered until the design level of limit roll rate is approached. For the illustration of Fig. 12 a design rate limit level of 220° per sec. has been selected. The aileron angle after initial full deflection is seen to be reduced by the automatic control to maintain approximately the desired 220° per sec. rate of roll. With maintenance of the roll rate at this level the roll maneuver proceeds for several revolutions to final check by the pilot with negligible excursions in sideslip and normal load factor.

The advantages of such a roll rate limiting control as opposed to limiting the amount of roll power provided lie in the ability of such a control to yield high initial roll acceleration and high peak roll rate at high load factor entry conditions. These advantages are achieved by provision of a large amount of inherent roll power utilizing the automatic control to contain roll rates to desired values. The design implications of the selection of such an automatic roll rate limiting control lie in the degree of complexity introduced and in the considerations of safety in the event of failure of such a control.

The success of a roll rate limiting control of the type discussed depends upon the provision of sufficiently high natural frequency levels to allow rate limiting below these values at a satisfactory roll performance level. For flight at extremely high altitudes, the requirement for reasonable rolling rates will demand excessively high stability levels in order to achieve the requisite natural frequency values. For this reason approaches to the solution of the roll coupling problem by means of automatic control devices other than roll rate limiting become of interest.

Another type of device potentially capable of producing satisfactory roll behavior lies in an automatic control to tailor, artificially, the natural frequencies of the configuration in pitch and yaw over the flight Mach Number and altitude spectrum. Such a possibility is directly suggested by the results of reference 1.

Investigations in this area, however, have shown that the simple criterion of equal natural frequencies in pitch and yaw does not always guarantee satisfactory response. This approach to the solution of the high-altitude flight problem must be explored in detail for each particular configuration in order to determine the proper levels of natural frequency in pitch and yaw to obtain satisfactory characteristics.

In conclusion, increasing speed and altitude capability of modern fighter aircraft will amplify the severity of the inertia coupling problem. In order to guarantee satisfactory rolling characteristics, attention must be focused in the preliminary design stage on a large variety of aerodynamic characteristics. These include static stability margins, effective dihedral, lateral control characteristics, and damping characteristics. A variety of automatic devices demonstrate the capability to eliminate unstable roll maneuvers. In applying these devices attention must be given to reliability and fail-safe considerations.

Reference

[1] Phillips, William H., *Effect of Steady Rolling on Longitudinal and Directional Stability*, NACA TN 1627, June, 1948.

▲ ▲ ▲

Flight Testing Stability Augmentation Devices for High-Performance Fighters

More sophisticated test techniques for today's more complex equipment and a standard tracking maneuver for proof of ultimate worth.

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North American Aviation, Inc.

Introduction

Five years ago, if an engineer suggested to a pilot that a given aircraft stability or control deficiency be remedied by the addition of a "black box," the pilot would have regarded him as a complete sadist. This early distrust of black-box stability and control devices for fighter airplanes is understandable for several reasons. First, the equipment was relatively large for installation in airplanes of approximately one half the gross weight of today's fighters. Second, reliability was poor. Third, performance was frequently objectionable as evidenced by excessive feedback to the pilot's control systems. Finally, the need for such devices was less pronounced since the range of performance of fighter aircraft 5 years ago was considerably less than it is today.

Today the picture is different. The state of the art in electromechanical design has advanced to the point where, with subminiaturization, black-box stability and control devices have been reduced to a more tolerable proportion of control system weight. This is particularly true considering the hard fact of increase in the gross weight of fighter aircraft over the past 5 years. Moreover, reliability has been improved, and fail-safe design has minimized the seriousness of a failure. The almost universal switch from reversible to irreversible control systems for fighter aircraft in the past 5 years makes it possible to remove all objectionable feedback to the pilot's control system. Please note that this is presented as a possibility, not necessarily an accomplished fact. Most important of all, however, is the simple truth that the range of performance of today's fighter aircraft has exceeded the designer's ability to provide satisfactory inherent stability for all flight conditions of which the airplanes are capable. For example, a vertical tail that gives satisfactory directional stability in the landing pattern and at high subsonic speeds may be entirely inadequate at supersonic speeds; damping in pitch may be satisfactory subsonically and intolerable supersonically. In brief, to make effective weapons systems of our present-day fighters, augmented stability devices are required. This is not always dictated by the inability of the designer to provide satisfactory inherent stability aerodynamically but frequently because it costs less in terms of weight and performance to do the job electromechanically. To illustrate this growing need for augmented stability, Fig. 1 shows the deterioration in basic damping of the short-period longitudinal mode over three generations in the genealogy of fighter aircraft. Moreover, the period of this mode, as illustrated in Fig. 2, has not increased over that of yesterday's aircraft, and the pilot is incapable of damping oscillations of such a short period through his basic control system.

Looking to the future, fighter aircraft altitude and Mach Number capabilities will increase, their densities will become greater, aerodynamic effectiveness of control surfaces will become relatively smaller, and the ever-growing problem of inertial coupling accompanying such advances will become a major design factor. For the fighter of the future, therefore, augmented stability devices will be not only a highly desirable appendage to improve weapons systems effectiveness but rather an absolute necessity to maintain adequate control of the aircraft to the limit of its performance potential.

Scope

Stability augmentation devices for fighter aircraft may be divided into two basic classifications:

(1) Those devices which improve basic aircraft open-loop stability without consideration for pilot inputs. Such devices operate independently of control deflections by the pilot and include yaw dampers, pitch dampers, roll dampers, and static longitudinal stability augmenters usually referred to as "Mach boxes."

(2) Those devices which improve closed-loop system stability where the loop is closed by the pilot and which

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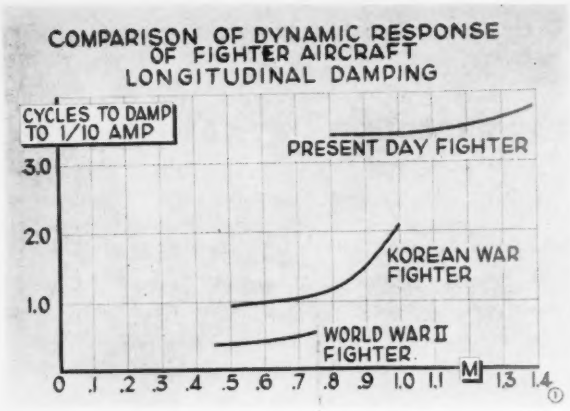
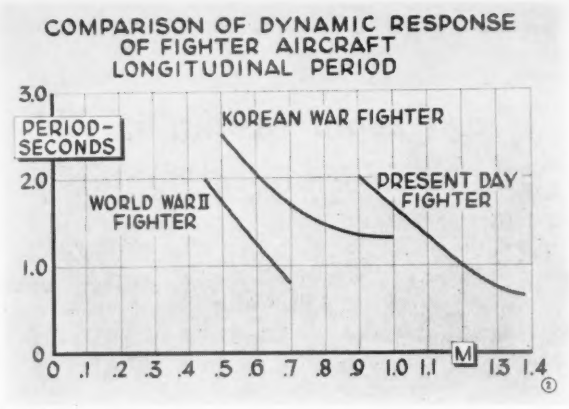




FIGS. 1 and 2.

take into consideration the pilot's problem in directing his aircraft with minimum effort and maximum kill probability. These devices include (a) artificial feel for irreversible control systems; (b) optimum gun line orientation, range limiters, and optimization of the sight coupling constant for fixed-gun fighters with disturbed line fire control systems; and (c) optimum error dot sensitivity and presentation stability for fighters with automatic tracking, director-type fire control systems.

A third classification might include those devices which improve the stability of closed-loop systems where the loop is closed by an automatic flight control system. However, since autopilots rarely prove much smarter than human pilots, the stability augmentation equipment noted in the two aforementioned categories pretty well covers those required by the automatic systems. Although tests of only the first category of stability augmentation will be discussed in this article, certain applicability of the test techniques described here to the test of closed-loop devices should be obvious, and the better understanding of the human pilot's problem through test acquaintance with the autopiloted system will be briefly considered.

Safety

Since flight safety is a matter with which the test pilot is daily concerned, it does not seem inappropriate to include at this point some remarks on that subject not only with regard to actual flight testing but also concerning safety in design concepts of stability augmentation devices from the pilot's point of view.

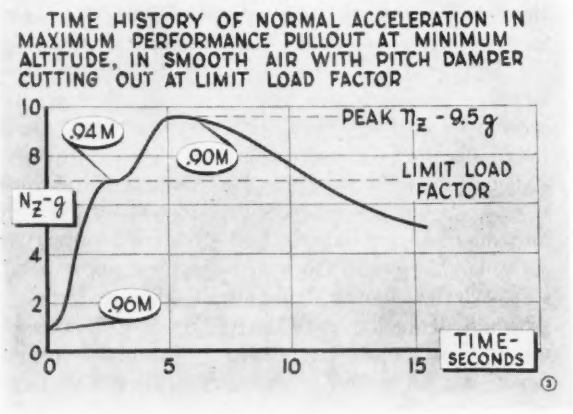
Initial testing of the various devices discussed above is usually done before fail-safe features have been incorporated, much less tested themselves. Thus, until proper fail-safe features have been well proved, it is imperative that test programs for most stability augmentation mechanisms be set up with deep respect for the implications of Murphy's First Law which reads in effect, "If it can fail, it will." Hardly less important is the corollary to this axiom, Murphy's Second Law, which states, "If it can be hooked up backwards, someone will do it." For example, there is the case where a prototype, full-authority autopilot was engaged at a high "q" flight condition, apparently with the pitch servo attached backwards. The resultant maneuver twisted the wings, ripped the engine from its attaching bolts, and left it lying in the tailpipe; and although the aircraft was landed safely, its thoroughly bent condition rendered it beyond economical repair. The lesson is simple—until fail-safe characteristics are well established by flight test, no stability augmentation device should be engaged at a flight condition where a maximum-rate, full displacement can structurally damage the airplane.

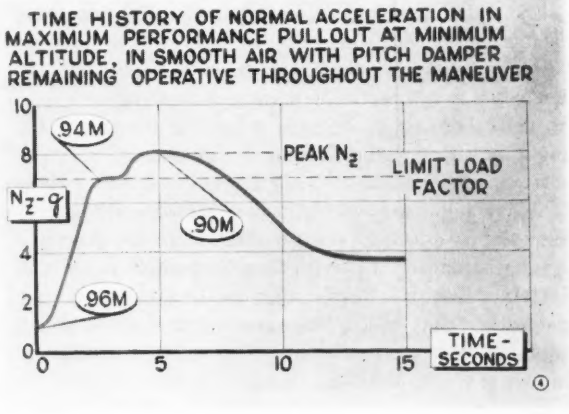
I have felt for some time that another safety problem inherent in the subsequent addition of stability augmentation in today's aircraft lies in possible changes in control systems vibration and flutter characteristics. As improved production articles are evolved from their flying prototypes, the original simple irreversible hydraulic controls of the first model may see the addition of damping about one or more axes, a change in the artificial feel bungees, and eventually perhaps incorporation of a full authority autopilot. Such changes will normally change effective mass, spring constants, damping ratios, and friction bands of the control systems. Couple these changes with ever-increasing aeroelastic effects on aerodynamic surfaces, control cables, and actuating arms, and a problem area could be developing. Consequently, flutter and vibration limits established for the original configuration should be carefully approached as major changes in control systems are effected. Recently I felt completely vindicated in this stand when the outboard section of a horizontal stabilizer failed in flight as a result of excessive vibration under high "q" conditions. This occurred at flight conditions which were well below the limits established by an earlier flutter and vibration flight-test program. However, the airplane that experienced the failure had had both a pitch damper and an autopilot installed since the original flutter and vibration tests and was being flown with both engaged at the time of the failure.

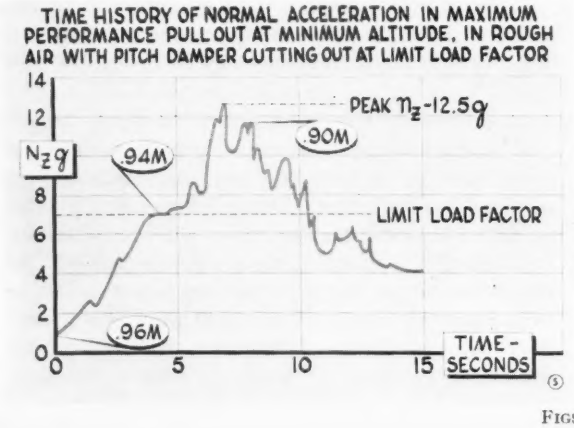
To leave the story at this point would certainly sup-

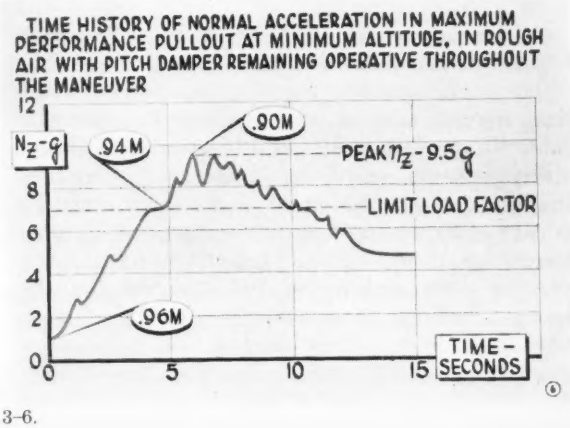
port the contention that stability augmentation devices can have deleterious effects on vibration and flutter characteristics. In all honesty, I am forced to confess that the culpability of the autopilot-pitch-damper installation has since proved dubious though it has not been altogether dismissed. However, I include these remarks on flutter and vibration because the stability of closed-loop systems is always worthy of respect and because aircraft hydraulic control system chatter has been observed with a frequency approximating the natural frequency of the surfaces on which the control systems operate.

Because of the high response rates required of present-day stability augmentation devices, much emphasis has been placed of late on the incorporation of fail-safe features into the design of all control system equipment. Unfortunately fail-safe in purpose is not always fail-safe in performance. Nuisance disengagements of dampers, autopilots, and associated equipment as a result of a malfunction of a fail-safe device are often much more frequent than routine failures of the basic equipment itself and infinitely more frequent than the hard-over signal against which the fail-safe feature is designed to protect. Furthermore, it should be emphasized that many stability augmentation devices in today's and especially tomorrow's high-performance aircraft are in themselves flight safety articles on which an airplane may well depend for safe maneuvering in certain flight regimes. For a simple example, imagine a high-performance fighter bomber making a low-altitude glide bombing attack and pulling out over the target at the limit load factor of the airplane. Suppose this airplane commences its pull-out at 0.96 Mach Number and the limit load factor is 7*g*. Further, suppose that it is equipped with a pitch damper and this pitch damper is protected by a *g* limiter device which cuts the pitch damper out at the limit load factor of the airplane. And while we are supposing, it may not require a stretch of the imagination to allow this airplane to have a stick lightening or pitch-up characteristic while decelerating through the 0.94 to 0.85 range of Mach Number in its pull-up. A time history of this aircraft's normal acceleration in such a maneuver performed in smooth air might look like that shown in Fig. 3. The pilot pulls the limit load factor of the airplane in order to clear the terrain and is about to stabilize at 7*g* when his airplane, decelerating rapidly, enters the pitch-up Mach Number range. With the pitch damper cut out by the fail-safe *g* limiter device, before the pilot can make adequate correction, the airplane has exceeded its limit load factor by 2.5*g*. A time history of a similar maneuver is shown in Fig. 4; however, in this case the pitch damper is allowed to remain operative throughout. As the airplane approaches the pitch-up range of Mach Number, the pitch damper senses the increase in pitch rate faster than the









FIGS. 3–6.

pilot can, automatically reducing the overshoot in limit load factor from 2.5 to 1g. Now let us put the airplane through the same maneuver again, only this time let it be performed in rough air and let the g limiter cut out the pitch damper at the limit load factor. A time history of normal acceleration in this situation might resemble that shown in Fig. 5. Here the pilot needing the maximum load factor performance of his airplane to clear the terrain successfully is trapped into almost certain structural failure by the combination of rapid deceleration into a pitch-up regime in the presence of heavy turbulence—having been denied the use of his pitch damper by a supposedly fail-safe device just when it might have done him the most good. Now if the taxpayers will permit, let us take a new airplane and try the maneuver just once more, again in rough air, but with the pitch damper operative throughout. Fig. 6 shows what a time history of normal acceleration might look like in these circumstances. Here it is seen that the pitch damper reduces peak load factor not only by anticipating pitch-up but also by reducing the excursions in normal acceleration caused by the turbulence. The airplane would no doubt survive the maneuver undamaged.

To summarize, pilots desire the maximum protection possible from hard-over types of failure in control systems, but they cannot tolerate nuisance disengagements as a result of failure of the fail-safe protection itself or as a result of improperly designed fail-safe features which can deny them the assistance of automatic stability augmentation just when they may need it most. To give the pilot what he needs, fail-safe features must be considerably more reliable than the devices they protect. Moreover, it may be necessary to deny fail-safe protection in certain regions of the flight envelope rather than run the risk of nuisance disengagements at critical flight conditions where stability augmentation about one or more axes may be essential for adequate control of the aircraft. Also in a combat situation, it may be found expedient to by-pass certain fail-safe features during the actual run on a target rather than risk a nuisance disengagement which would require a second run. This might be infinitely more dangerous than the chance of a hard-over failure and could preclude safe return from the mission because of fuel exhaustion.

On the more positive side, I envision as an approach to the optimum in fail-safe design a series of stops on the stability augmentation servo. These stops would limit the authority of the servo over the particular control surface it actuates as a function of speed and altitude such that a hard-over signal could not overstress the aircraft. The movement of the stops would be monitored by a parallel system for determining their correct positioning. Should they fail to sequence properly, a warning light would so inform the pilot, and he could make the decision whether or not his mission or flight condition dictated continued use of the device in question without fail-safe protection. This method does not arbitrarily shut off the stability augmentation it protects and yet gives protection for everything except a simultaneous double failure.

Flight Testing Basic Airplane Stability Augmentation

Only the flight testing of equipment for improving basic airplane stability will be considered in this article. The earliest of such items to appear in fighter airplanes was the yaw damper; since then, pitch dampers have become quite common, and the need for roll dampers is becoming more and more apparent with speed and altitude capabilities continuing to increase. As airplanes become capable of sonic speeds, a requirement for pitch trimmers to correct the transonic longitudinal trim shift developed. Flight testing of these various mechanisms will be treated first individually and then as a group.

Yaw Dampers

Early yaw dampers consisted of simple yaw-rate gyros which controlled a servo attached directly to the rudder control system. This equipment served simply to damp out basic directional oscillations of a relatively high frequency. Being attached directly to the control system, any action of the yaw damper was usually reflected back to the rudder pedals. Because of limited performance of the airplanes in which they were installed, it was rarely necessary to schedule damper gains as a function of speed or altitude. Testing of these devices usually consisted of finding a compromise gain setting which would give adequate damping for the flight envelope of the airplane. Determination of adequate damping was usually accomplished by observing residual directional oscillations after release of the rudder from constant heading sideslips.

Today's yaw dampers are not so simple. In addition to damping out yaw rate, they are expected to keep the airplane in directional trim and give turn coordination as well. Moreover, the greater performance capabilities of present-day airplanes have made it necessary to schedule all the inputs to the damper, usually as functions of both altitude and Mach Number. Concurrently, our pilots have become a more sensitive lot and will not tolerate feedback to their rudder pedals as the yaw damper performs its various chores for them; nor will damping that is less than optimum please today's less tolerant and more technically aware fighter pilot. The old technique of adequate compromise damping of constant heading sideslip rudder releases is no longer a valid test technique. Because of the various inputs to the yaw damper in addition to yaw rate (such as lateral acceleration, roll rate, and aileron position), any sustained uncoordinated maneuver will generate opposing control deflections by the damper which will give the erroneous appearance that the airplane, having been displaced originally from trim, is hanging up in an out-of-trim condition in the opposite direction upon release of the rudder. For this reason, the pulse technique for evaluation of basic damping is much

better; in fact, the double pulse technique (wherein one rudder is sharply displaced and released, followed with no interval by a similar pulse of the other rudder) has the most merit for avoidance of apparent but probably nonexistent bias problems. Use of this test method at the various flight conditions of which the airplane concerned is capable should allow the test pilot to select very near to optimum gain schedules for basic yaw damping. The optimum of course is 0.7 of critical damping which, if achieved, will give minimum tracking error in the presence of purely directional disturbances. Observance of the fixed sight pipper with reference to some point on a cloud or the horizon is a good method for optimizing basic damping. The turn and bank indicator because of its mounting angle and location above and ahead of the c.g. is generally a poor instrument for directional damping optimization. Yaw vanes with remote indicators in the cockpit and yaw strings mounted ahead of the windscreen are fair indicators but in general are less sensitive than the fixed sight pipper. Normally, optimum basic damping is attained when the pipper, after centering of the rudder at the end of the double pulse, makes one overshoot past the trim position, which overshoot should have an amplitude of 10 to 20 per cent of the peak yaw disturbance input. Further increase in the gain should eliminate the overshoot altogether, but the initial return to trim will take longer. Sometimes, as gains are increased to what appears to be optimum damping, a small residual oscillation is observed. Further increase in gain may increase the amplitude of this residual oscillation. This is evidence of approach to high gain instability. If a lower gain below this instability region, as evidenced by disappearance of the small residual oscillation, does not give adequate basic damping, an increase in the ratio of rate feedback to proportional feedback in the damper loop will probably allow higher gains before approaching this instability problem.

In addition to purely directional disturbances, however, our more sophisticated breed of yaw damper is designed to correct for adverse or favorable yaw, as induced by roll rate or lateral control displacement, and will maintain directional trim as well. Observing the alignment of the fixed sight pipper with the horizon or other horizontal reference during small and large lateral control displacement rolls throughout the range of performance of the airplane should give a good picture of how well the yaw damper is correcting for adverse or favorable yaw conditions on turn entries. Base line data of identical maneuvers with the yaw damper off will give the test pilot an opportunity to familiarize himself thoroughly with the problems the yaw damper is trying to correct and enable him to change the gains at his disposal in the proper directions as he optimizes for each flight condition.

To check operation of the lateral accelerometer feature, which is designed to keep the airplane in directional trim, simply displace the airplane approximately one-half ball width out of directional trim in constant heading flight either through the aircraft directional trim system or by use of the rudder pedals. Without retrimming from the cockpit or changing rudder pedal pressure as appropriate, the airplane should be returned slowly to zero sideslip angle upon engagement of the yaw damper.

Pitch Dampers

The need for artificial damping in pitch for fighter aircraft is relatively recent and one that is concerned primarily with supersonic flight at high altitude. At high altitude where the air, or damping fluid, is much thinner and at supersonic speeds where the restoring force, or spring constant, is relatively greater, very few if any fighter aircraft will be found to have adequate longitudinal damping.

In evaluating pitch dampers, optimum basic damping of pitching oscillations must first be determined. This is accomplished by making an abrupt pull-up to 2*g* and releasing the stick. Damping of the subsequent pitching oscillation is best determined, as with optimization of the yaw damper, by observing the fixed sight pipper and its motion with respect to some fixed horizontal reference. Again, as with the yaw damper, the desired optimum is 0.7 of critical damping which is evidenced by one overshoot past the trim position equal to between 10 and 20 per cent of the pitch disturbance at the instant of stick release. Since airplanes are not normally symmetrical about the pitch axis, optimized gains should be checked by observing longitudinal damping after a pushover to zero *g* and release of the stick. By applying this technique throughout the range of performance capabilities of the airplane in question, satisfactory damping of basic longitudinal oscillations may be determined. In embarking on such a program, the pilot should first observe the basic airplane characteristics in identical maneuvers with the pitch damper off. The process of optimization should then start in that area of the flight envelope where damping is most obviously needed. At low altitude and low speed, for example, longitudinal response rates of most fighters are relatively slow, and damping of pitch disturbances in this area of the flight envelope is comfortably within the response capabilities of the human pilot. To attempt to optimize a pitch damper at such flight conditions may well compromise its performance at high altitude and high Mach Number where it is really needed.

Unlike the yaw damper, which operates on a control which is rarely used except for trim by the pilots of modern fighters, the pitch damper operates on a control which is continuously in use, frequently at maximum rates of displacement. As a consequence, any opposition of the pitch damper to pitch rate inputs by the pilot must be eliminated. To accomplish this, properly amplified pilot inputs of longitudinal stick force and stick rate are combined to wash out inputs to the pitch damper servo. Optimization of these quantities can be accomplished through air-to-air and air-to-ground

tracking and formation flying. All three should be done if possible in both smooth and turbulent air. If the pitch damper appears to be pushing the airplane in the direction of the pilot's control deflections, pilot effort inputs to the pitch damper are too large; if the pitch damper noticeably opposes the pilot's direction of the airplane, pilot effort inputs are too small. Where the pitch damper appears alternately to lighten and stiffen longitudinal stick force gradients, response rates of pilot effort inputs are improperly matched to those of the pitch damper.

Roll Dampers

The requirement for roll dampers in fighter aircraft is for the most part not yet clearly established. In fact, when the pilot is left out of the loop, the term "damper" is not an accurate one since, for the basic airplane of normal configuration, rolling oscillations do not occur. What sometimes is required is a device which will increase the time constant of the spiral divergence of an airplane so that the pilot does not have to give roll attitude constant attention while trying to maintain wings-level flight during climb and cruise. The need for such a device first came to my attention during the course of an autopilot development program wherein it was observed that a rolling oscillation of relatively short period and small amplitude persisted in the cruise condition regardless of the setting of available gains on the roll axis of the autopilot. To cure this problem, a highly unsophisticated roll damper was evolved which had a total authority of less than one degree of aileron and went to full throw in opposition to roll rate sensed by the roll rate gyro of the autopilot. Incorporated into the roll axis of the autopilot, this device eliminated the aforementioned rolling oscillations. The interesting sequel is that in the same area of flight conditions in which the autopilot was experiencing roll oscillations, the human pilot was experiencing the same difficulty. By allowing this poor man's roll damper to continue to operate with the autopilot turned off, manual handling characteristics of the airplane were improved. Unfortunately the device was not designed with this in view and the small aileron impulses were fed back to the stick, which feedback was found to be objectionable. Another problem in the development of roll dampers, particularly those of the very limited authority, full throw variety, is the danger of inducing very small but perceptible oscillations in pitch and yaw at flight conditions other than those for which the device was originally optimized.

Flight test and evaluation of roll axis stability augmentation devices should include formation flying, mission profile flights with external stores if applicable, and tracking both air-to-air and air-to-ground. Also using a lateral pulse of controlled magnitude with the airplane trimmed in straight and level flight and measuring the time required to roll to 30 degrees of bank angle with roll damper *on* and roll damper *off*, a picture of improvement in spiral divergence characteristics can be obtained. Because of the uncertainties of random inputs from turbulence or failure to return precisely to the same trim after each test as a result of control system friction, at least four samples of each pulse-divergence test should be recorded.

The Mach Box

To correct for the trim shift which accompanies acceleration through the transonic range, the Mach box has been devised. This mechanism continuously repositions the horizontal stabilizer as a function of Mach Number such that stick force stability is always positive or at worst neutral. Such devices are normally evaluated first in level flight accelerations and decelerations through the significant Mach Number range recording longitudinal stick force throughout. Each run should be made commencing from a trimmed stabilized condition, and no change in trim should be made by the pilot during a run. More exacting tests consist of high g level turns commenced at a Mach Number above the trim shift or a steep dive in full power commenced at a Mach Number below the trim shift. At all times, the pilot is looking for constant stick force gradients along with the absence of jerky stick movement and abrupt transients.

The Common Problem of Artificial Open-Loop Stability

It is to be noted in the foregoing remarks on devices for augmentation of basic aircraft stability that one of the biggest problems for the designer is the fact that he is expected to supply the desired basic stability characteristics without the pilot being aware of their artificiality. Not only must these devices give good open-loop damping about their respective axes or supply static longitudinal stability at transonic speeds, but they must provide these same services with the pilot in the loop without giving objectional feedback to the stick or rudder. Whether or not these requirements are being fulfilled is best determined by how accurately and effortlessly the pilot can direct the airplane throughout its tactical range of speed and maneuverability. To better determine the answer to this question, a standardized tracking maneuver is described in the next section, the use of which maneuver is suggested as a supplement to the techniques already presented.

A Standardized Tracking Maneuver

The purpose of a tracking evaluation for stability augmentation devices is twofold. First, it is designed to uncover any undersirable or adverse characteristics not discovered by the test techniques outlined in the preceding paragraphs. Second, it aids in determining the true tactical value of the device under scrutiny by measuring the improvement it contributes in stability and control characteristics as evidenced by decrease in both mean tracking error and overall pilot effort.

A standardized tracking maneuver for the evaluation of fighter stability augmentation devices is illustrated

in Fig. 7. It should be pointed out from the start that considerable variation in this maneuver is permissible to meet the peculiar tactical requirements or performance capabilities of a given model fighter; however, once an evaluation program is started, the maneuver as modified should be adhered to as closely as is practical. The procedure is for the pilot of the tracking airplane to position himself behind the target at a range of approximately 2,000 ft and zero range rate with the target at the predetermined speed and altitude for the start of the maneuver. Upon a signal from the tracking airplane, the target commences the maneuver and the pilot of the tracking airplane does his best to keep his fixed sight pipper on the tailpipe or other preselected aim point of the target. Sight camera film from the tracking airplane should be run throughout the maneuver simultaneously and in correlation with other instrumentation determined necessary for the requirements of the test.

In planning a program using this or a similar maneuver, certain factors should be considered to obtain the most significant results. If possible, the target should be the same model airplane as that used for tracking. This is important in order that the acceleration and deceleration characteristics of the two airplanes will closely match one another. Thus, the tracking pilot will be relieved to some extent of the range control problem and can better concentrate on tracking. Once the pilot (or pilots) is selected for the tracking program, he (or they) should be allowed to follow it through completely. Should substitution of a pilot become necessary, the new pilot should start from the beginning and run through the entire test program. The number of maneuvers required for evaluation for a given device will vary depending on the complexity of the equipment being tested and the nature of the learning curve for the airplane-pilot combination. In any case, at least every third run should be a base line maneuver performed with the device under test, and it only, turned off. For example, if a pitch damper is being evaluated in an airplane previously equipped with a yaw damper, base line maneuvers as well as pitch damper tests should be flown with the yaw damper operative.

Instrumentation for a tracking evaluation program can range from none at all to very elaborate. With no instrumentation, complete reliance is placed on the pilot's qualitative remarks as to tracking accuracy, pilot effort, and learning curve. With the addition of sight camera film, quantitative data on tracking accuracy and the learning curve are obtained and only tracking effort is left for qualitative evaluation by the pilot. If the complete instrumentation job is done with oscillograph showing control forces, normal acceleration, and the like, pilot qualitative evaluation fills the role of reporting the degree to which measured variations in pilot effort are objectionable and what manner of control system feedback to stick and rudder is tolerable.

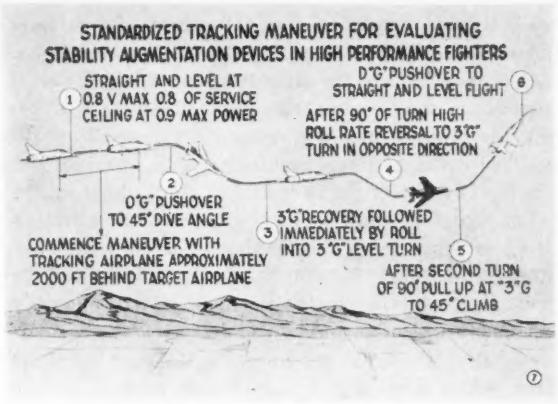

STANDARDIZED TRACKING MANEUVER FOR EVALUATING STABILITY AUGMENTATION DEVICES IN HIGH PERFORMANCE FIGHTERS
1 STRAIGHT AND LEVEL AT 0.8 V MAX 0.8 OF SERVICE CEILING AT 0.9 MAX POWER
2 0"G" PUSHOVER TO 45° DIVE ANGLE
COMMENCE MANEUVER WITH TRACKING AIRPLANE APPROXIMATELY 2000 FT BEHIND TARGET AIRPLANE
3 3"G" RECOVERY FOLLOWED IMMEDIATELY BY ROLL INTO 3"G" LEVEL TURN
4 AFTER 90° OF TURN HIGH ROLL RATE REVERSAL TO 3"G" TURN IN OPPOSITE DIRECTION
5 AFTER SECOND TURN OF 90° PULL UP AT "3"G TO 45° CLIMB
6 D"G" PUSHOVER TO STRAIGHT AND LEVEL FLIGHT
7

FIG. 7

There are some interesting facets to the analysis of pilot opinion which might properly be discussed here in brief. First impressions are important. The most complete report on a new piece of equipment by a given pilot will be obtained after his first flight. Anything encountered that is different from previous experience normally will be reported; and if it is not a decided improvement, it will most probably be reported as objectionable. For instance, a pilot used to heavy longitudinal stick force gradients may, on first evaluating a new control system with very light stick forces, report it as unsatisfactory because of a tendency to overcontrol an airplane which before he had been forced to "horse" around. Subsequent flights may find the same pilot an enthusiastic supporter of the new light force gradient. Other characteristics reported as unsatisfactory on first flight evaluations may be more neutral. A force stick for a maneuvering autopilot, for example, may occasionally exhibit a very low amplitude, high frequency hum which on being first encountered will probably be reported as unsatisfactory. However, as more experience is gained with the equipment, the pilot may report it as present but not objectionable—or not report it at all. This indicates that this particular characteristic is one which it would be nice to eliminate but also one which in no way affects the tactical utilization of the airplane. A third category of items found objectionable on first flights are those which the pilot no longer reports after several subsequent flights but which may actually be giving him trouble though he has learned unconsciously to anticipate and compensate for them. For example, a pilot may initially report that a pitch damper is needed under certain flight conditions, then report on subsequent flights that he can track just as well without it. Evaluation of pilot effort during subsequent tracking maneuvers may well show that he is working twice as hard to obtain the same quality of tracking without the pitch damper as he is with it. A fourth category of pilot first-flight squawks is the one that continues undiminished through the evaluation and usually this discrepancy will be found to be one that must be corrected. When pilots of the same experience level

with the equipment are found to be in mild disagreement on the advantages or optimization of a given device, chances are the differences are so small that no significant improvement is involved. Where a new pilot is brought into a program, his opinions, particularly for the first few flights, must be interpreted in the light of the foregoing remarks on first-flight impressions, especially when comparing his opinions with those of a pilot who has spent some time on the program. To summarize, pilot first impressions are important but must be validated by subsequent tests; pilots are extremely adaptable and may appear to perform equally well with an inferior system if the learning curve and pilot effort are ignored; and where the opinions of several pilots with equal experience appear widely scattered, the differences involved are likely to be insignificant.

In assessing data from tracking maneuver evaluations, it is usually more important to note the time required to re-establish steady tracking after the various transients introduced by the maneuver rather than to measure the tracking errors present once steady tracking has been resumed.

Conclusions

In review, it has been noted that artificial stability augmentation is changing from a desirable appendage to an absolute necessity as performance capabilities of our fighter aircraft continue to increase. This being the case, improved fail-safe design is required. With increase in performance capabilities of our fighters, more sophisticated stability augmentation devices are being evolved which require in turn more elaborate techniques for their evaluation and optimization. The final proof of a stability augmentation device lies in its performance in the tactical range of speed, altitude, and maneuverability at which the airplane is designed to operate. To approximate this condition, standard tracking maneuvers are designed for determination of the ultimate worth of the device under test as measured by tracking accuracy, the learning curve, and pilot effort.

▲ ▲ ▲

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Various types of power plants for VTOL aircraft are discussed; emphasis is placed on the importance of VTOL aircraft for defense, industry, and the individual.

Power Plants for VTOL Aircraft

Peter G. Kappus
General Electric Company

How do we go about reaching the tempting goal of true VTOL? Many ingenious devices have been suggested; some of them have already been tested, or are currently being developed. All of them depend, to a large degree, upon the most basic key to practical VTOL—a propulsion system of extremely high thrust/weight ratio. It cannot be emphasized strongly enough: "*Practical VTOL capability will be reached only through power plants of extremely low weight, combined with acceptable cruise fuel consumption!*" It will not be achieved through the use of conventional "off-the-shelf" engines designed for conventional applications. One may well wonder why large amounts of research and development funds are being expended to develop radically new VTOL air-frame concepts, whereas not enough is being done to attack the problem at its roots, the propulsion system.

It has been frequently stated that VTOL may well happen as an almost incidental phenomenon caused by the higher and higher speed requirements of advanced military aircraft which lead to a steady increase in take-off thrust/weight ratio. This thinking misses one of the most important aspects of modern jet propulsion. Our latest engines build up much of the required high speed thrust as a result of their own speed in a fascinating boot strap operation. The thrust at high supersonic Mach Numbers has little relationship to the take-off thrust, and we can visualize engines powerful enough to propel airplanes with Mach Numbers as high as the structure can stand, and yet, delivering a take-off thrust considerably below gross weight. The other point is that there are a great many important applications for VTOL where supersonic speed is not needed and where cruise thrust requirements are quite modest. In this case, a propulsion system of extremely wide power range is required, combining very high take-off thrust with a cruise thrust at good fuel economy of less than 10 per cent of full power. Here, the required flight performance of the engine is far under the power level needed for VTOL. To sum it up, VTOL will not just happen. We have to make a determined effort to create propulsion systems with novel and very specific characteristics, representing new advances in power/weight ratio which combine efficiency at very low partial load with tremendous take-off power.

Many previous publications have dealt with an astounding variety of possible VTOL vehicles, ranging from the flying bedstead to the pogo stick and the coleopter. One of the most important objectives in the near future should be a thorough investigation and evaluation of the most promising VTOL engine systems properly matched with air frames that utilize their inherent capabilities to the fullest extent and result in the ideal engine-air-frame combination for the various military and commercial requirements. It is possible to draw up a "family tree" of VTOL engines that shows quite some variety in the propulsion field. Our tree has two main branches leading to engines for wing-supported systems on one side, and for purely thrust-supported vehicles on the other side.

The engines for winged aircraft may be divided into three groups. First, a system is conceivable where separate engines are used for cruise and lift. This would be a simple answer to the need for a wide span of power between hovering and cruise. Next, we can differentiate between thrust converters designed to produce cruise thrust in horizontal direction and lift at a 90° angle to the thrust line, and attitude converters where cruise and take-off thrust vector have the same direction with the whole airplane changing its attitude, as in the case of the pogo stick or the coleopter. In the thrust converter group, we have turbojet, turboprop, and turbofan converters. Similarly, the attitude converters, generally called "tail sitters," can be built with extremely light, but otherwise conventional, turboprop, turbojet, or turbofan engines. The coleopter uses power plants in both the jet and the fan or ducted propeller class. Thrust-vector conversion can be obtained either by rotating the whole engine assembly, as in the tilt wing turboprop and the rotating jet or fan installation, or by adding a suitable piece of hardware, such as a rotating tailpipe or cascades, to a jet engine or slip-

This paper is slightly condensed from the paper of the same title presented at the VTOL-STOL Aircraft Session, IAS 25th Annual Meeting, N.Y., Jan. 28–31, 1957. The author's complete work is available as IAS Preprint No. 667.

The author is Manager—New Product Planning, Flight Propulsion Laboratory Department, Aircraft Gas Turbine Division.

stream deflectors to a turboprop. The latter arrangement is not considered part of the engine, and it is gratefully acknowledged that aerodynamicists and structures people are willing to take responsibility for this tricky development.

More elaborate thrust converter systems could use tipmounted turbofans with cascades for thrust vector conversion or a turbojet, for cruise thrust, which converts into a high bypass ratio turbofan for vertical lift and hovering. Turboprop thrust converters may use no mechanical interconnection between the propellers. They may have shafts and bevel gears connecting the propellers for added safety, or they may utilize a common gas generator and pneumatically interconnected propeller turbines.

Turning back to the wingless vehicles, we find pure rocket propulsion as one extreme possibility for interceptors and missiles, and air-breathing turbojet or turbofan engines in several variations. A turbojet-supported platform vehicle is an example for an approach which produces lift through moderate mass flow of high specific energy. The shaft-turbine-driven helicopter represents the other extreme, using a high mass flow of low energy for lift. The turbofan-supported vehicle may use a mechanical shaft and gear drive between power generator and fan, or pneumatic power transmission, driving the fan through a tip turbine, mounted on the outer rim of the lift-producing fan.

No claim can be made as to the completeness of this classification; any number of combinations of various propulsion systems not listed, as well as entirely new ones, are possible.

I would like to point out four distinctly different power plants that seem to offer special advantages for certain applications. First, for a tilt wing utility and assault VTOL transport of fairly conventional appearance, a turboprop arrangement, as shown in Fig. 1, seems to deserve attention. Instead of two separate but mechanically interconnected turboprop engines, a central gas generator could be used. This unit is identical with a turbine compressor unit of a modern lightweight free-wheeling turboshaft engine. The hot pressurized gases produced by it are ducted through the tilted wing to free turbines, driving the two propellers over reduction gears. The power output could be increased for take-off through the use of interburners, raising the gas temperature before entering the propeller turbines. In comparison to the mechanically interconnected separate turboprop solution, this arrangement offers numerous advantages in mechanical simplicity, weight, cruise economy and, possibly, reliability, and seems well worthy of closer evaluation.

For high-speed applications with short hovering times, a simple cluster of four lightweight turbojet engines, installed as illustrated in Fig. 2, may have merits. All four engines run at full take-off power during hovering, take-off, and landing. The jet is directed downward through cascades which permit slight variations in thrust direction in order to build up speed. After the wings produce adequate lift, two of the four engines are shut down, and the mass flow from the remaining two is directed through a suitable flap door valve to a tailpipe, thus producing cruise thrust in the horizontal direction. This system promises early availability, using fairly conventional engines of very light weight at high subsonic speeds. It has a high fuel flow during the hovering phases, but this may well be offset by the attractively low weight of the complete propulsion system.

A similar but more elaborate arrangement, shown in Fig. 3, uses two turbojet engines large enough to satisfy the cruise speed requirements but not powerful enough to produce sufficient direct lift. For take-off and hovering, the turbojet mass flow is utilized to operate a tip turbine mounted on the rim of a fan rotor that converts the small high-energy mass flow of the turbojet into the large, low-energy mass flow of a high bypass ratio turbofan or ducted propeller. This conversion results in adequate lift and produces a hovering s.f.c. approximately 1/2 to 1/3 of that of a turbojet, making the trade-off of hovering time vs. range more favorable than in the preceding example.

Finally, a short-range high-speed vehicle with relatively favorable hovering consumption, whose size is not much larger than an automobile, could be developed which is purely thrust supported and saves all the weight and bulk as well as some of the drag caused by wings. It is illustrated in Fig. 4. Here, two small gas generators drive a ducted fan by means of a rim turbine that produces the required lift and thrust forces. Its axis is set at an angle to the vertical since the thrust vector produced must coincide with the resultant of weight and drag. This intriguing vehicle comes quite close to Dr. Lippisch's idea of an Aerodyne.

It should be emphasized that the four examples mentioned do not necessarily represent the best possible solutions to the various military and commercial requirements. They have been selected mainly to indicate possible variations and to encourage critical evaluation of these and other promising VTOL power plants. It is believed that reliability and early availability of power plants, combined with low development costs, may possibly be the most important considerations in the early phases of VTOL technology. It also seems worthwhile to present a simplified analytical approach intended to illustrate the relative range capability of various VTOL propulsion systems.

The main question to be answered is, what specific engine weight, combined with which level of cruise fuel consumption, is required to make possible a desired range and pay-load capability?

Another interesting aspect is the effect of hovering s.f.c. on range. The following is an attempt to point out an extremely simple and, it is hoped, useful method to illustrate the relationships involved.

Using terms of specific interest to the propulsion engineer, the well-known Breguet Formula can be modified for the VTOL trajectory shown in Fig. 5. The term ϕ takes into account the hovering time during climb and descent where no range is covered. Note that

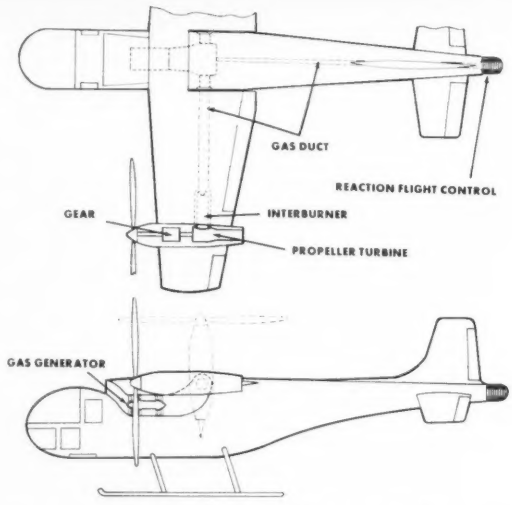


FIG. 1. Turboprop for VTOL aircraft. (Principle: Two or four pneumatically interconnected propeller turbines powered by a common gas generator. Application: Tilt wing or slipstream VTOL aircraft.)

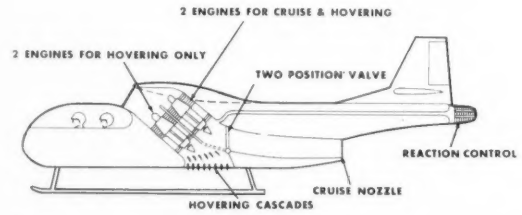
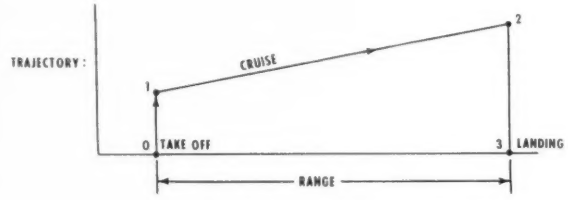


FIG. 2. Turbojet propulsion for VTOL aircraft. (Principle: Four lightweight turbojets, for take-off and landing two are shut down, two produce thrust during cruise. Application: Fixed-wing high-speed VTOL aircraft with short hovering time.)



BREGUET RANGE FORMULA FOR VTOL VEHICLES:

a) FOR WING SUPPORTED VEHICLES:

$$R = L/D \times \frac{V}{sfc} \times \ln\left(\frac{\phi}{\frac{W_{(S+L)}}{W_0} + \frac{F_{SLS}/W_0}{F_{SLS}/W_p}}\right)$$

b) FOR THRUST SUPPORTED VEHICLES:

$$R = W/D \times \frac{V}{sfc \times \sqrt{1+(W/D)^2}} \times \ln\left(\frac{\phi}{\frac{W_{(S+L)}}{W_0} + \frac{F_{SLS}/W_0}{F_{SLS}/W_p}}\right)$$

FIG. 5. VTOL flight performance evaluation. {R = range (nautical miles), L/D = lift to drag, V = cruise speed (knots), s.f.c. = specific fuel consumption (lbs./lb. hr.), $\phi = [(1 - \text{s.f.c.}_0) \times (F_{SLS}/W_0)(t_{0-1})/(1 + \text{s.f.c.}_3)(F_3/W_3)(t_{2-3})]$, t = hovering time at take-off and landing in hours, F_{SLS} = take-off thrust (lbs.), W/D = weight to drag, $W_{(S+L)}$ = weight of structure and pay load (lbs.), W_p = weight of power plant (lbs.), W_0 = T.O. gross weight (lbs.).}

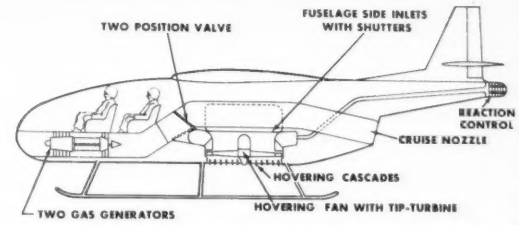


FIG. 3. Convertible turbofan for VTOL aircraft. (Principle: Two lightweight gas generators operate as turbojets for cruise. For take-off and landing they drive a fan through a tip turbine. Application: Fixed-wing high-speed VTOL aircraft with long hovering time.)

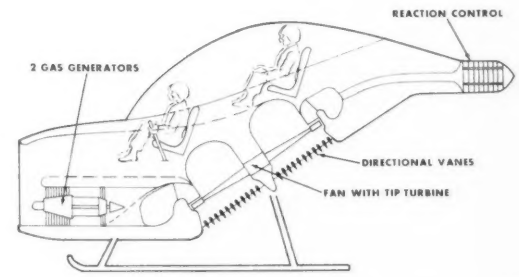


FIG. 4. Turbofan propulsion for a thrust-supported VTOL vehicle. (Principle: Two lightweight gas generators drive a turbofan through a tip turbine which produces both lift and thrust. Application: Wingless high-speed VTOL liaison and observation vehicles for moderate range.)

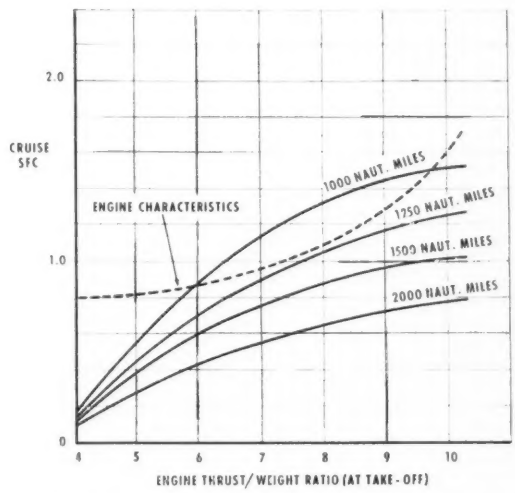


FIG. 6. Relationship of range and engine parameters for a winged VTOL aircraft. (Assumptions: $L/D = 12$, $V = 450$ knots, $t_{0-1} = t_{2-3} = 4$ min., s.f.c.$_0 = 1.3$, s.f.c.$_3 = 1.1$, $W_{(S+L)}/W_0 = 0.50$, $F_{SLS}/W_0 = 1.2$, $F_3/W_3 = 1.2$.)

SYSTEMS:	TILTWING TURBOPROP	FIXED WING, TURBOJET CLUSTER CASCADE CONVERTER	FIXED WING, CRUISE TURBOJET CONVERTED INTO FAN FOR HOVERING	NO WING, TURBOFAN THRUST SUPPORTED
CRUISE SPEED kn	300	450	400	500
CRUISE L/D OR W/D	14	12	12	1
CRUISE SFC	.7	1.15	1.2	.25
HOVERING SFC	.18	1.2	.4	.4
AIRFRAME WEIGHT lbs.	3000	2800	2800	1800
PROPULSION WEIGHT lbs.	2400	1500	1400	1200
FUEL WEIGHT lbs.	2600	3700	3800	5000
HOVERING FACTOR Φ	.986	.908	.968	.968
RANGE n.mi.	1720	1715	1780	930

FIG. 7. Range capabilities of various VTOL power plants. (Common assumptions: gross weight = 10,000 lbs., pay load = 2,000 lbs., T.O. thrust = 12,000 lbs., total hovering time = 4 min.)

in this form the Breguet Formula contains the main power-plant characteristics—s.f.c. and engine specific weight. Assuming a certain speed and aircraft characteristics considered obtainable, the relationship of cruise s.f.c. and engine specific weight required to obtain a specified range can be plotted.

For thrust-supported vehicles, a similar relationship, introducing the ratio of weight to drag in place of the aerodynamic L/D parameter, can be derived in analogy to the Breguet Formula.

Fig. 6 shows a plot of the relationship of cruise s.f.c. and specific engine weight with range for the assumptions noted. It is now also possible to plot in the same graph the relationship between s.f.c. and specific engine weight considered available for a family of engines with different turbine inlet temperatures, pressure ratios, or bypass ratios representing the possible state of the art in turbojets or turbofans. In this manner, one can easily identify the most promising combination of engine weight and fuel consumption for maximum range and for the air-frame characteristics and hovering time assumed. The engine resulting in maximum range for the conditions assumed is represented by the point on the curve of engine characteristics that comes closest to the highest range curve.

A few comments are in order with regard to the use of the modified Breguet Formula for thrust-supported vehicles. Here, it is important to remember that the drag term D used in the formula includes both the aerodynamic drag of the vehicle as well as the ram drag which is equivalent to the flight speed impulse of the mass flow utilized by the engine. In a sense, this ram drag can be considered to be analogous to the induced drag of a wing. Depending upon the bypass ratio used, the ram drag may become several times as high as the aerodynamic drag of the vehicle itself.

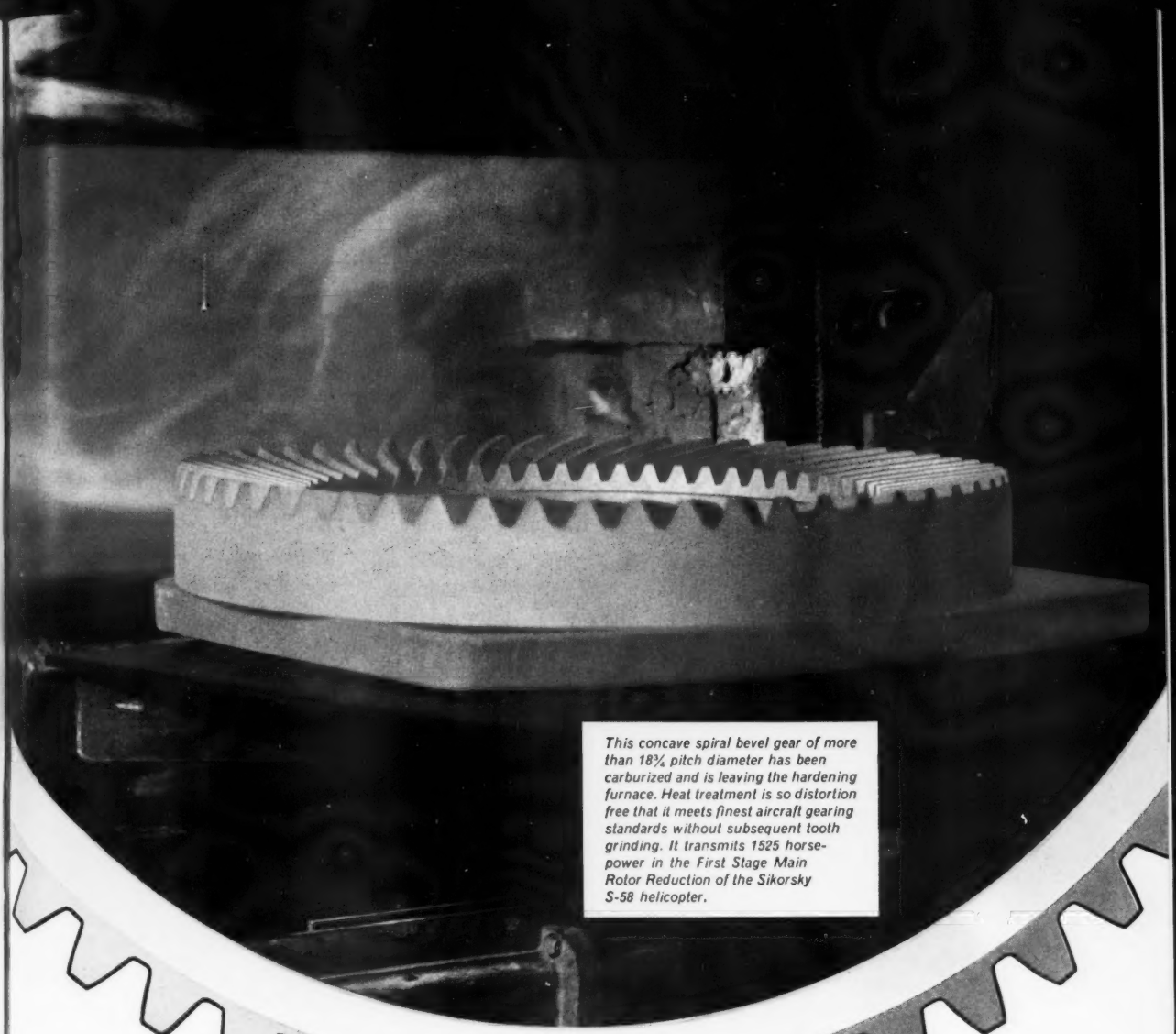
Using the simplified analytical approach outlined in Fig. 5, the range was calculated which would be obtainable with the four different VTOL engines discussed. To make the comparison simple, it was assumed that all vehicles have a gross weight of 10,000 lbs. and carry a load of 2,000 lbs. The cruise speed was varied in accordance with the basic capabilities of the power plants considered. Assumptions were made for the aerodynamic and structural characteristics of the air frame and also for the power-plant characteristics influencing the range. No claim is made as to the absolute or relative validity of these assumptions; they serve only for the purpose of illustrating the use of the analytical method presented.

Fig. 7 summarizes the assumptions made and also the total range obtained under these conditions. If the characteristics of actual VTOL aircraft and propulsion systems are as assumed in this table, the three winged aircraft investigated are quite competitive in range capability. The thrust-supported vehicle is considerably lower in range performance and especially in fuel economy, but its high speed, low bulk, and simplicity make it quite interesting in spite of its shortcomings in range.

It was possible to touch only very lightly on the fascinating subject of VTOL power plants in the short space available. In conclusion, it must be stated that many of the VTOL power plants mentioned will require considerable effort on the part of the engine manufacturer, both in the area of hardware development and in the preceding phase where it must be decided largely through analytical evaluations and design studies which of the many possibilities should be developed.

It does not appear practical to go ahead and try out all of them. Already our research and development capacity is strained to the limit through the many complex high-priority projects aimed at supersonic and hypersonic, as well as commercial, applications. We will have to concentrate on the few most promising solutions in order to give to the Armed Forces and, it is hoped, to commercial operators and ultimately to the individual complete air mobility with all the revolutionary consequences which will be the result of the successful achievement of practical VTOL.

▲ ▲ ▲



This concave spiral bevel gear of more than 18¾ pitch diameter has been carburized and is leaving the hardening furnace. Heat treatment is so distortion free that it meets finest aircraft gearing standards without subsequent tooth grinding. It transmits 1525 horsepower in the First Stage Main Rotor Reduction of the Sikorsky S-58 helicopter.

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WHY BE LIMITED IN YOUR CHOICE OF FLIGHT DIRECTORS?

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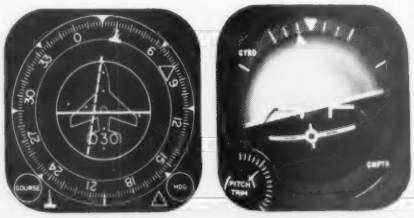
To show the wide range and flexibility of Bendix* Flight Director Systems, let's assume an ILS approach situation in which the airplane, on a 20° heading, is in a 10° right bank with its nose on the horizon, but slightly above the glide slope. The Course Deviation Indicator (same on all Bendix systems) pictures actual and pre-set headings, TO-FROM indications, and position relative to ILS beams (or VOR radial). Now, let's see how attitude reference and command information are presented on three typical Bendix Flight Director Indicators.

COURSE DEVIATION INDICATOR

FLIGHT DIRECTOR INDICATOR

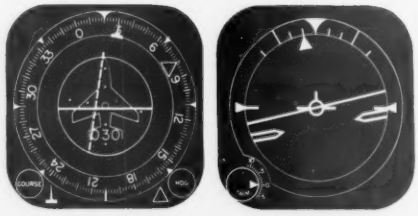
BENDIX SERIES "300" SYSTEM

In this system the Flight Director Indicator presents computed roll and pitch commands. Sky and ground are represented on a sphere, as shown, and actual attitude is depicted by conventional airplane symbol. Secondary airplane symbol represents commanded attitude and, in this case, calls for nose-down, left bank maneuver. Command is satisfied when the two symbols coincide.



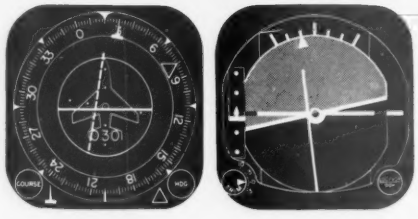
BENDIX SERIES "100" SYSTEM

This system's Flight Director Indicator also shows computed steering commands in both roll and pitch axes. Sky and earth presentation is flat rather than spherical, and white line represents horizon. In this version, the two pointed, opposing markers designate commanded attitude. Command is satisfied when wingtips of airplane symbol align with markers.



BENDIX SERIES "200" SYSTEM

The Flight Director Indicator in this system provides for computed steering commands in roll axis only. Flat gray and black areas represent sky and ground. Command bar is needle-like line extending up from bottom of indicator, and, in this example, calls for left turn. Commanded attitude is attained when this needle is straight up and down through center of indicator. Small horizontal bar's position with relation to vertical white dot scale along left edge shows whether airplane is above, below, or on glide slope beam.



With Bendix Flight Director Systems you have your choice of several types of presentation . . . and your choice of a single- or two-axis system. You *don't* buy features you don't want or need. Yet, you get all the features and advantages that you *do* want and need. When you think of flight directors, think of Bendix. Get the Bendix story.

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TETERBORO, N. J.

Bendix
AVIATION CORPORATION

(Continued from page 27)

perature range at which austenite transformed to martensite and also decreased the amount of martensite formed. However, when pressure was removed at temperatures below 0°C., the same amount of martensite was formed as would have been formed on cooling to a like temperature without pressure.

About the same amount of martensite was formed isothermally on holding at −125°C. in specimens cooled under atmospheric pressure and in those cooled under 6,500 kg./cm.² hydrostatic pressure.

Microscopic examination showed no detectable effect of pressure on the resultant martensitic structure.

The data contained in this paper seem to be accurate. Similar work has been accomplished in the United States at the Massachusetts Institute of Technology. The steel used (containing 0.5 per cent C, 0.4 per cent Mn and 20 per cent Ni) was somewhat similar to 40GN20. After oil quenching from 1,095°C. and stress relieving at 480°C., both the M_s and M_b temperatures (the temperature at which martensite begins to form in bursts) in the unstressed conditions were about −37°C. Cooling under a hydrostatic pressure between 2,000 and 4,000 atmospheres resulted in M_b temperature of −78°C.; the M_s temperature could not be determined with certainty. Thus this amount of hydrostatic pressure lowered the M_b temperature about 40° C. In the Soviet work the M_b temperature was not determined, but it was found that a pressure of about 4,000 atmospheres lowered the M_s temperature about 40°C. This agreement seems satisfactory and points toward the reliability of the Soviets.

It is unfortunate that Stregulin and Chuprakova did not investigate other types of stresses, as the M.I.T. work indicated that uniaxial compression gave results quite different from hydrostatic or triaxial compression.

U.S.S.R. Harbors Open Early as Planes Powder River Ice

◆ The Soviets have reported the successful development of a very effective and economical method for hastening the thawing of spring ice. In Northern climates harbors become usable in the spring without the aid of expensive ice-breaker ships only after the ice has melted. Also, river ice, after the spring breakup, may create temporary ice dams causing sudden and damaging floods.

The Soviets claim that treated ice melts 15 to 20 days earlier than untreated ice. They cite examples where harbors were made usable earlier in the season, and the level of flooding was greatly reduced by the early removal of selected areas of river ice. They also cite a special example where ice removal by the new method cost only 1/60th as much as it would have cost using ice-breakers.

The Soviets state that their method consists essentially of distributing, by airplane, a blackening substance which not only has good heat-transfer properties to destroy the ice thermally but also destroys the ice structure chemically. The powder, heated by the sun's rays, melts the ice. Although such a practice appears to be highly objectionable, the Soviets claim that an oily liquid having a poor vaporizing factor is then sprayed on the ice to retard evaporation of the water by melting, thus further speeding up the melting process.

The most effective, and the least expensive, blackening substance found has been salvaged foundry sand. Depending upon the nature of the spring season and upon the thickness of the ice, 260–440 lbs. of sand per acre are distributed from an altitude of approximately 15 ft. If more intensive ice destruction is desired, 5–10 lbs. of salt per acre is added. Refinery residue from the manufacture of diesel oil is used as the oily liquid for retarding evaporation. The originators of this method claim that the total cost of treating the ice is about $9.00 per acre (using a rate of exchange of 4 rubles for 1 dollar). It is planned to use 1,000 tons of black powder for dusting ice at the port of Archangelsk this year.

Electron Microscope Work by Soviets Is Held Excellent

◆ A Soviet paper titled "Study of Intragranular Mosaic Structure of Austenite by Means of the Electron Microscope," by Ye. I. Kvashnina, reveals high-grade work with the electron microscope. The paper, while routine to some degree, contains excellent electron micrographs.

An electron microscope was used to study the grain structure of three austenitic grades quenched from 1,150°C. At a magnification of 7,500 x, it was possible to examine the intragranular block (mosaic) structure and to differentiate the zone near to the grain boundaries from the structure in the interior of the grains.

Of the grades tested:

1Kh18N9T is similar to AISI type 321. The titanium content is on the low side to give full protection against intergranular corrosion. Moreover, the solution temperature of 1,150°C. is considerably higher than the temperature normally used in the United States (about 925/950°C.). The higher solution temperature would undoubtedly increase the hot strength but may also make it more susceptible to intergranular corrosion. The current Cornell investigations have shown that this high solution temperature combined with the relatively high carbon content (0.11 per cent) would give a decided improvement in 100-hour rupture strength at 1,500°F. over titanium-free steel of the same carbon content (about 10,000 vs. 7,000 psi). It appears probable, therefore, that this steel is intended for elevated-temperature service.

EI 402 is analogous to AISI type 347 but the columbium content of 1.2 per cent is somewhat high compared to the carbon content of 0.09 per cent. This relatively high columbium content would normally be expected to give problems in fabrication. In the U.S.S.R., titanium-stabilized 18–8 seems to be most common for corrosion resistance where columbium-stabilized or extra-low-carbon 18–8 would be used in the United States. It appears, therefore, that EI 402 is applied more for elevated-temperature service than for corrosion-resistant parts. Skubachevskiy has stated that EI 402 is used for various parts of jet reaction nozzles and afterburners and that a 50°C. higher limiting temperature is permissible with it than with 1Kh18N9T.

EI 448 would seem to be roughly equivalent to AISI type 318, but with titanium rather than columbium as a stabilizer. In view of the recent Cornell work, however, this may be underestimating Soviet metallurgy; the titanium may be present for elevated-temperature strength rather than for prevention of intergranular corrosion. For the carbon content and solution treatment involved, this addition of about 0.5 per cent Ti would be expected to increase the 100-hour stress-rupture strength at 1,500°F. from about 7,500 to 10,500 psi.

IAS News *(Continued from page 25)*

the Guided Missile Division of the Navy Bureau of Aeronautics. Before his promotion, Dr. Barmby was Aeronautical Administrative Engineer.

Philip E. Culberston (M) has become associated with the Bendix Aviation Corporation Systems Division, Ann Arbor, Mich., as Head of Aerodynamics and Propulsion. He formerly was Staff Engineer to the Vice-President, Engineering, of Convair, A Division of General Dynamics Corporation.

Harold Frearson (M), formerly with Orenda Engines Limited, Canada, has joined Ryan Aeronautical Company, San Diego, Calif. as Coordinator of Quality Control.

Morton J. Friedenthal (A), who has been on active duty as an Aeronautical Engineer at the USAF Wright Air Development Center, is now a member of the Guided Missile Research Division, The Ramo-Wooldridge Corporation, Los Angeles, Calif.

Arthur W. Gilmore (M), formerly Assistant Professor (acting), Department of Aeronautical Engineering, University of Colorado, has accepted a position as Head, Aerophysics Group, Grumman Aircraft Engineering Corporation. Mr. Gilmore had been Secretary of the IAS Rocky Mountain Section.

Frederick M. Gloeckler (AF), Head, Air Warfare Research Department, Naval Air Development Center, Johnsville, Pa., has been promoted to the super-grade position of GS-16, the Navy announced.

Eugene V. Gustavson (A), formerly Administrative Engineer, Lockheed Aircraft Corporation, Georgia Division, has been appointed Director of Engineering, Aeronca Manufacturing Corporation.

Major J. Vivian Holman (M), has joined the Boards of Adam Engineering Co., Ltd., Vonarx Repetition Co., Ltd., Hasler Sales Company, and V. H. M. S. Enterprises Ltd. His address will be 4 Orange Street, St. Albans, Herts, England.

Captain Grayson Merrill (AF), who retired from the Navy July 1, has been appointed Director of Engineering, Fairchild Engine and Airplane Corporation Guided Missiles Division. Capt. Grayson's last active duty assignment was Technical Director, Special Projects Office, Bureau of Ordnance.

Leonard M. Michal (A), former Supervisor, Regulus Support Group, Chance Vought Aircraft Inc., has become a member of the Guided Missile Research Division, The Ramo-Wooldridge Corporation, Los Angeles, Calif.

Arthur E. Miller (M), has been promoted from Chief Engineer to Director of Research at Scott Aviation Corporation.

Glenn M. Peters (M), has joined Temco Aircraft Corporation, Dallas, Texas as a Senior Aerodynamics Engineer. He formerly was associated with H. L. Yah Company of Philadelphia, Pa. as an Aerodynamicist.

Marvin B. Ruffin (AM), former Vice-President-Sales, Summers Gyroscope Co., has joined Chicago Aerial Industries, Inc., also as Vice-President, with responsibility for directing the company's growth in aviation electronics and missile systems fields.

David B. Watson (A), formerly an Aerophysics Engineer for Convair Division, General Dynamics Corporation, has joined Temco Aircraft Corporation as a Senior Aerodynamics Engineer.

Everett T. Welmers (AF), formerly Chief of Dynamics, Bell Aircraft Corporation, has been appointed Director of the Lawrence D. Bell Research Center.

S. X. Xifo (M), who was General Supervisor of Missile Flight Test for Northrop Aircraft, Inc., has been promoted to Chief of Missile Field Test.

Necrology

Conrad F. Nagel, Jr.

Word of the death of Conrad F. Nagel, Jr. (AF), retired Vice-President of Aluminum Company of America and outstanding metallurgist, has been received by the Institute. Mr. Nagel died July 5, after a long illness, at his home in Pittsburgh.

A native of New York and a graduate of Cornell University, he developed the process for producing feathered aluminum for use in explosives. Mr. Nagel has been credited with establishing aluminum as a major material for aircraft by determining and eradicating causes of excessive corrosion in the 1920's.

He joined Alcoa in 1915, served as an infantry lieutenant in France during 1917–1918, and returned to Alcoa in 1919 to head the process and products division of the firm's Technical Direction Bureau.

Mr. Nagel became Chief Metallurgist for Alcoa in 1944 and was elected a Vice-President in 1952. He also served as Chairman of the firm's technical committee which guides and supervises all company technical activities.

CORPORATE MEMBER NEWS

• **Allis-Chalmers Manufacturing Company** has published Bulletin 14B8615, *Allis-Chalmers a.c. Motor Starters and Contactors*, describing the firm's complete line from 50 to 100 hp. Copies are available at the firm's headquarters, Milwaukee 1, Wis.

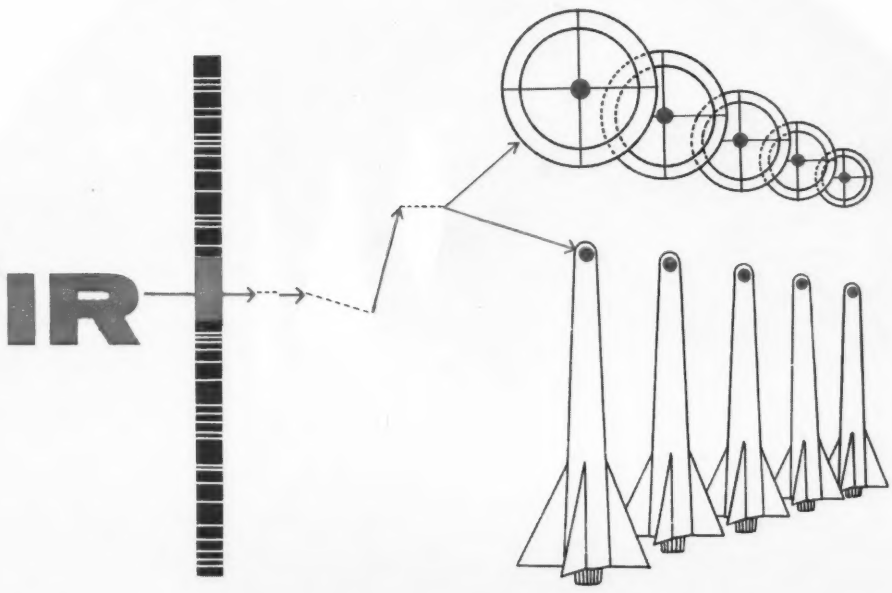
• **Aluminum Company of America** is using a 17-in. television receiver to check close tolerances of a newly developed die-layout machine. Alcoa reports the method permits production of large dies to extremely close tolerances.

• **American Airlines, Inc.,** has announced the first nonstop service between Boston and Los Angeles scheduled to begin August 1. The firm also announced completion of major renovation of its passenger facilities at New York's LaGuardia Airport.

• **Amphenol Electronics Corporation** has announced the formation of Amphenol Great Britain Ltd., a new subsidiary operating in Alperton, England, and owned jointly by Amphenol and Gas Purification and Chemical Co., Ltd. . . . The firm also has announced cable-to-chassis types have been added to its Micro-Ribbon series of connectors with availability in 14, 24, 36, and 50 contacts. Also available is a new high-temperature Teflon Hook-Up wire made to MIL-W-16878B specifications.

• **Bell Aircraft Corporation's** X-14 VTOL aircraft is powered by two British-made Armstrong Siddely jet engines, the firm announced. Designed to take off vertically in a conventional horizontal position, shift to forward flight, and land vertically, the X-14 differs from "tail sitter" VTOL in that it operates without ground handling equipment to position it for take-off. Thrust diverters or vanes located behind the engines direct the jet blast toward the ground to lift the plane into the air. Compressed air nozzles at wing tips and tail provide directional control. The forerunner of the X-14 has been given to the Smithsonian Institute, for its National Aeronautical Collections. . . . The firm has announced acquisition of 350 acres near Pembroke, N.Y., as a site for its new Lawrence D. Bell Research Center.

• **Bendix Aviation Corporation,** Products Division, has announced a new "module" type of gas-turbine fuel control test equipment for sale to aircraft manufacturers and overhaul organizations. . . . Radio Division has begun an aircraft-collision-avoidance research program aimed at a practical anticollision device for the ARDC. The division also announced the appointment of Ernest A. Duquet as Chief Engineer for the design of air traffic control systems. . . . Red Bank Division has announced that a new, reportedly high gain, germanium PNP



INFRA-RED

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audio power transistor (designated 2n-285A) is in full-scale production.

• **Boeing Airplane Company** reports that the Air Force has approved in principle its proposal to assemble and deliver the B-52G at the firm's Wichita, Kan., plant. The proposal is designed to realize savings in procurement costs by eliminating the use of Seattle, Wash., facilities from the program. Seattle will be the site of a Bomarc training school for Air Force, Boeing, and subcontractor personnel, the firm said. The school, to be located on Harbor Island, will simulate a complete base.

• **Cornell Aeronautical Laboratory, Inc.,** has announced installation of a large-scale IBM 704 Computer, composed of 13 different machines and soon to include a total of 20. The laboratory also has published a report evaluating the quality and uniformity of titanium used by the aircraft industry in 1956.

• **Douglas Aircraft Company, Inc.,** El Segundo Division, has developed a light-weight intercommunications system using transistors instead of vacuum tubes. The division reports the improved system has demonstrated excellent audio qualities and greater reliability during operational use with the Navy's A3D Skywarrior and AD-5Q Skyraider.... The firm also announced it is using a new direct reading temperature indicator only one-thirtieth the size of any previous equivalent in the flight testing of military and commercial aircraft.... The first Douglas WB-66D weather reconnaissance version of the B-66 Destroyer was scheduled for delivery to the Tactical Air Command at the end of June.

• **Ethyl Corporation** has announced a new antiknock compound for aviation gasoline which reportedly permitted a 20 per cent power gain during tests using a Curtiss-Wright 18-cylinder turbocompound engine. Designated AK-33X, it is an organic compound of manganese.

Boeing Airplane Co. has announced that the first KC-135A Jet Stratotanker to be placed in operational service has been delivered to the Strategic Air Command, 93rd Air Refueling Squadron.

• **Fairchild Camera and Instrument Corporation** has announced a Voice Data Link System which, the firm says, can convert automatic commands from computing machines into verbal messages.

• **Fairchild Engine and Airplane Corporation** has announced availability of Rolls-Royce R Da 7 MK 525 engines to power the firm's F-27.... Savings reportedly more than $6 million under the original fixed-price contract for tooling and production of C-123's have resulted in a refund of $4.7 million to the Air Force, the firm announced.... Also announced were plans to expand plants to the Aircraft Division, Engine Division, and Stratos Division.... Joseph Matolina, Jr., has been appointed Director, Quality Department, Engine Division.

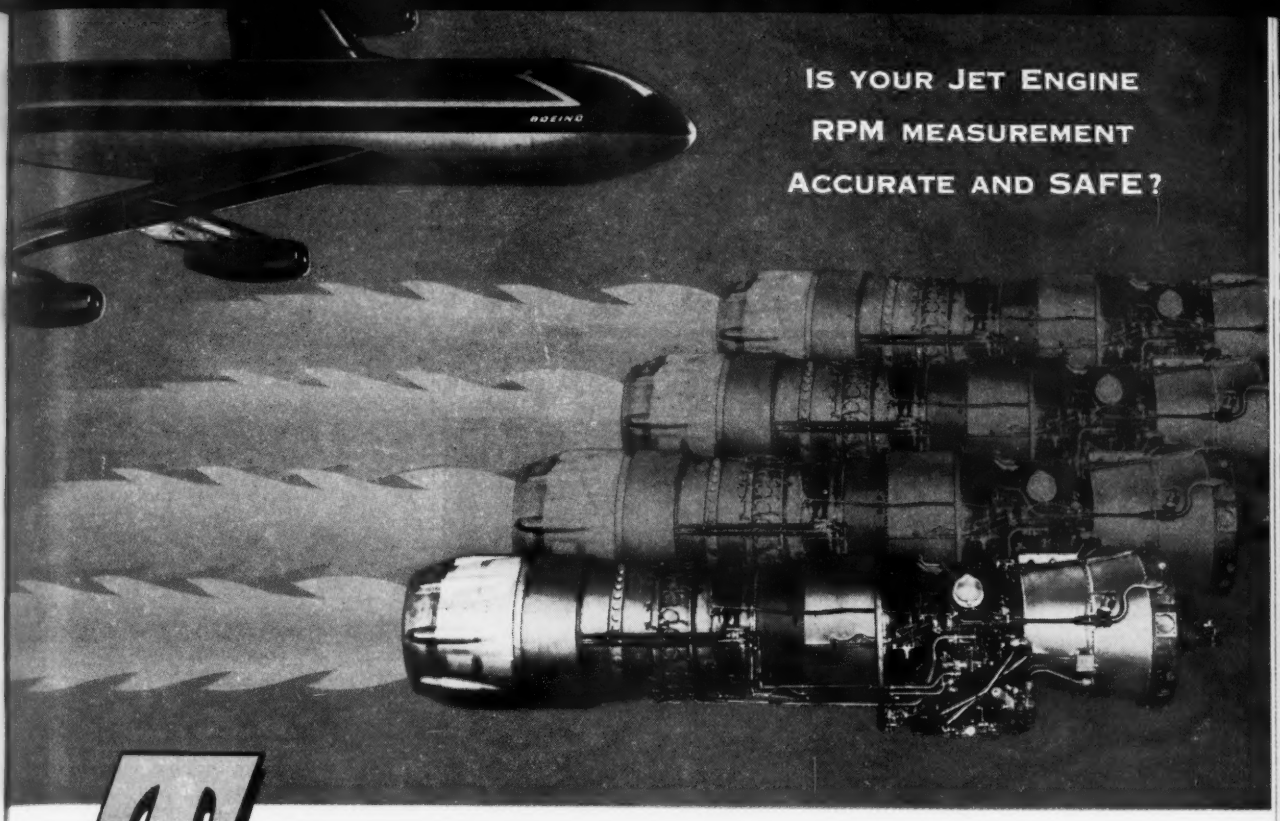
A new executive plane designated "Design 159" is being developed by Grumman Aircraft Engineering Corp., re-entering the commercial airplane market after a 7-year absence. Two Rolls-Royce Dart Turboprop engines will power the pressurized plane which will carry 12 passengers at 370 m.p.h. maximum at 25,000 ft. Maximum range is said to be 2,200 miles, gross weight 31,000 lbs., wing-span 78 ft., and length 64 ft. Grumman says the first 159 is due off the production line in May, 1958.

• **Flight Refueling, Inc.,** has announced the appointment of Fred J. Kendall as Dayton Representative for the company.

• **The Garrett Corporation,** AiResearch Manufacturing Division, Los Angeles, Calif., has developed the pneumatic pressurization system for Convair's 880 jet transport with auxiliary electrical controls which can be operated by the pilot at any time. The auxiliary is operated by a cockpit switch consisting of an electromechanical actuator on each outflow valve, the firm reports. The division also announced it will supply pressurization and air conditioning equipment for Japan's Fuji Aircraft Company jet trainer.

• **General Dynamics Corporation,** Convair Division, has delivered its 1,000th transport, a Metropolitan 440, to Eastern Air Lines, Inc., at San Diego, Calif. Announcement that drop tests of the detachable pods carried by the B-58 have begun at Kirtland AFB was made from the division's Fort Worth facilities.... Kenneth Stiles has been named to the newly created corporate post of Vice-President—Plans and Programs.

• **General Electric Company,** Chemical & Metallurigical Division, Silicone Products Department, has announced availability of a new silicone rubber compound designed for wire insulation. Designated SE-975, it was planned for use on aircraft wire, motor and apparatus lead wire, defroster and hook-up wire, atomic Navy cable, and other applications, according to the firm. Another new compound developed by the department is SE-701, which will be used on the Douglas DC-8.... Engineers in the Aircraft Gas Turbine Division's Small Aircraft Engine Department have developed an automatic welding machine that works from a roll of punched paper tape similar to a player piano. It is used to weld jet-engine cylindrical parts.... The Missile and Ordnance Systems Department, Defense Electronics Division, has announced installation of what it calls one of the most modern, efficient, and automatic processing and computation centers in the missile industry.... Industrial Electronics Division, Communication Products Department, has developed a new



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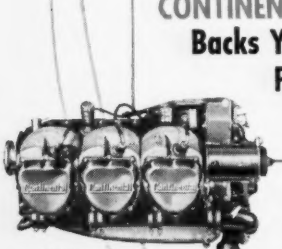
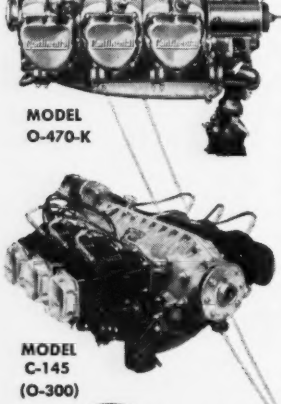
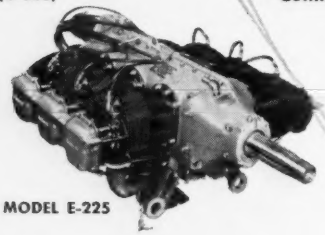


MODEL O-470-K



MODEL C-145 (O-300)



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• **General Precision Equipment Corporation,** General Precision Laboratory Incorporated, has announced a new line of video monitors for broadcast station or industrial and institutional television picture presentation with GPL or other closed-circuit systems.

• **The B. F. Goodrich Company** has announced the retirement of its President, William S. Richardson, and the election of J. W. Keener as President, Director, and Member of the Executive Committee.

• **The Goodyear Tire & Rubber Company, Inc.,** has designed and built a "tunneled" fuel cell to fit around the drive shaft of the Marines' land combat vehicle Ontos. . . Goodyear Aircraft Corporation's private-commercial nonrigid airship "Ranger" has transferred its base of operations from Miami, Fla., to Los Angeles, Calif., the firm reports.

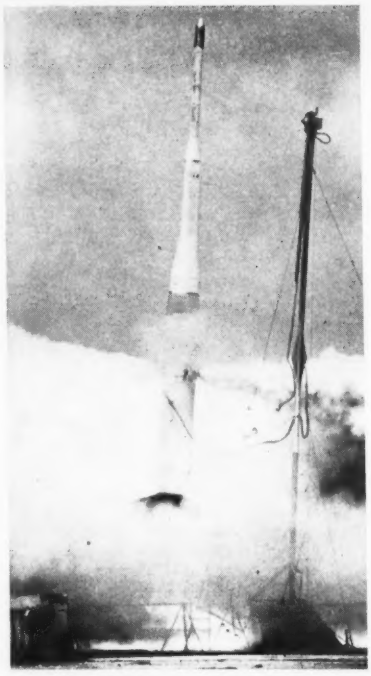
• **Johns-Manville Sales Corporation,** Packings and Friction Materials Division, has announced the appointment of Clinton R. Burnett as Vice-President and Division General Manager. He succeeds Francis J. Wakem, retiring after 36 years.

• **Koppers Company, Inc.,** has announced arrangements to buy a modern factory building at 141 East Hunting Park Avenue, Philadelphia, Pa., for its shaft steel manufacturing facilities..

• **Lear, Incorporated,** LearCal Division, has announced a new version of its "OmniMeter" and "Vortran," which the firm calls naturally oriented omni indicators. Model 4080 is an indicator only, applicable to any Arinc Vor system; Model 2372 Vortran combines indicator with an integral fully transistorized omni converter that can be applied to any VHF receiver that covers Vor frequencies. Faces of both instruments are identical in appearance and function. Edward F. Conklin has been appointed Division General Manager.

• **Liberty Aircraft Products Corporation** has announced completion of an expansion program of hydraulic manufacturing facilities, and assembly and test areas which are air-conditioned. The firm reports production of hydraulic and pneumatic assemblies and components for military and commercial aircraft has been doubled as a result. This now constitutes 25 per cent of Liberty's overall production. Current operations include production and prototype orders for Chance-Vought, Grumman, North American and Republic companies. A brochure of Liberty's hydraulic facilities may be had by writing the firm at Farmingdale, Long Island New York.

• **Lockheed Aircraft Corporation,** Missile Systems Division, has announced the use of sound waves, twice as high in frequency as the human ear can detect, to drill tiny precise holes in materials that high-speed drills cannot scratch. A drill specially designed by Nicholas K. Marshall, Senior Scientist at the division's research and development center, is powered by sound waves to bore microscopic holes in hard ferrite materials. . . . A cryostat (super-refrigerator) for producing liquid helium



Lockheed Aircraft Corporation's X-17 Air Force research rocket was reported by the Department of Defense to have reached the highest speed ever achieved by any instrumented missile. In the photo, spin rockets are shown emitting plumes of smoke from the side of the X-17. These give it a stabilizing twirl before being dropped in flight. The rocket is used for re-entry research.

and for scientific study of temperatures near absolute zero will be installed at the Palo Alto, Calif., laboratories. A completely "human engineered" command station to give engineers more sensitive control over missiles in flight has been completed at Holloman Air Development Center, the division announced. A specially constructed facility for design and testing of advanced missile antennas and radar devices will be built by the division near its Sunnyvale site. . . . Electra Notes—Installation of four Allison 501 prop-jet engines on a special Super Constellation "winged laboratory" has been completed. Electra flight engineering tests will cost $5.8 million, the firm reports. First choice for an Electra fuel is kerosene. . . . Georgia Division scientists assisted by ten specialist universities are setting up a project to test the endurance of pilots and crew members on extended flights. The division's nuclear aircraft research laboratory under construction in northern Georgia is scheduled to be in operation by the end of 1958. Hercules Notes—An endurance mark of 14 hours, 1 min. continuous flight was set recently for this type of troop-and-cargo plane, the division announced. A Tactical Air Command Hercules has completed maneuvers over the United States, Europe, Alaska, and Panama, making landings and take-offs, taxi-runs and aerial deliveries on sand, sod, steel planking, ice and snow, and short, hard-surfaced runways. The division also announced that the Marines will test a Hercules for possible use as an in-flight refueling tanker. . . . California Division has announced the appointment of Russell C. Galbraith as Director of Financial Operations. He had held the same position with the Georgia Division.

• **The Martin Company** has announced the 1,000th Matador guided missile has rolled off the firm's assembly line.

• **Minneapolis - Honeywell Regulator Company,** Aeronautical Division, has published a booklet describing the firm's hydraulic servos available for military and commercial applications. Stephen F. Keating, company Vice-President in charge of the Aeronautical Division, has been given corporate responsibility for directing all of Honeywell's activities in the military field. The company also reports transfer of most of its inertial guidance engineering staff to a new division facility at St. Petersburg, Fla.

• **Northrop Aircraft, Inc.** . . . Lt. Col. Desider A. Simcoe, Jr., is new USAF Plant Representative at Northrop, the firm announced.

• **Nuclear Development Corporation of America** has announced its third major expansion program with the purchase of a 63-acre site in Greenburgh, N.Y., which will serve as a research and development center. The company also announced the formation of a new firm, NDA Europe, owned jointly by the White Plains, N.Y., corporation and Societé Generale des Minerais of Brussels. Societé Belge pour l'Industrie Nucleaire also is a participant. NDA Europe will provide for rapid atomic energy development in the six Euratom countries and their colonies, possessions and territories, according to NDA America.

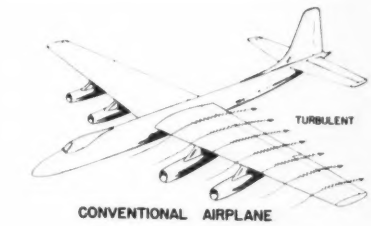
• **Pan American World Airways, Inc.,** Atlantic Division, has announced the appointment of Jesse L. Boynton as Regional Director—Middle East and Asia. Lloyd M. Wilson has been appointed Service Manager for the Division.

• **Reaction Motors, Inc.,** has announced the appointment of Joseph W. Antonides to the newly created post of Vice-President for Solid Propellant Operations. He also will continue as Executive Assistant to the President.

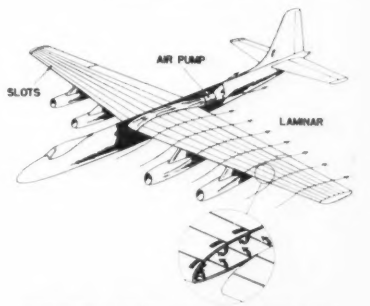
• **Republic Aviation Corporation** has developed a new device for testing 1,200 different aircraft electrical circuits in less than a minute. The new method uses an automatic circuit analyzer that is said to reduce the time for electrical checking from hours to less than 5 sec. for every 100 circuits. Glenn C. Bach has been named Chief Production Test Pilot.

• **Ryan Aeronautical Company** and the Navy have developed an "electronic intelligence" device, designated AN/APN-67, said to be a unique system of automatic aerial navigation for high-speed jet planes. (Another device, the AN/APN-97, is an outgrowth of the primary instrument which the firm says will provide more fully automatic operation of helicopters in hunter-killer antisubmarine operations. It is known as a helicopter hovering detector.) The electronic intelligence device is said to be the lightest, simplest and most compact in production, and to gather data instantly with "pin-point" accuracy. Ryan says an even lighter model has been developed for air-line use. Outstanding features, according to the firm, are no need for ground facilities or aerological data, operation over oceans and ground terrain in all weather, and provision of latitude, longitude, ground speed, desired and actual ground track, drift angle, ground miles traveled and course error. The instrument also can transmit and receive two continuous wave radar beams using only a single receiver-transmitter. . . . A Ryan Firebee jet drone has flown its 100th mission at Vincent AFB, the company announced. Another Firebee has been parachute-recovered 14 times in the desert at Holloman Air Development Center. Air Force pilots have begun familiarization training on a tethered test vehicle prior to flying the Ryan Vertijet X-13. One of the Vertijets was sent by ship through the Panama Canal en route to an undisclosed destination, the firm announced.

• **Solar Aircraft Company's** new 50-lb. gas-turbine aircraft engine for a one-man helicopter is 20 in. high, has a maximum diameter of 15.5 in., weighs only 50 lbs. and will produce 55 s.hp. plus 12 lbs. of jet thrust on a 100°F. day, according to the firm. . . . The firm also announced the appointment of Allied Supply Com-



CONVENTIONAL AIRPLANE



BOUNDARY LAYER CONTROL AIRPLANE

Scientists of Northrop Aircraft, Inc., and the Air Research and Development Command have evolved what they call a new design concept application that promises to increase the range and load-carrying capacity of aircraft. This application, based upon 7 years' intensive research in low-drag boundary-layer control, utilizes slots along the wings, fuselage, and tail surfaces (see drawing). Tests involving an F-94 showed friction drag was reduced to one-seventh of its normal value.

pany, South Gate, Calif., as distributor of Sola-Flex industrial expansion joints.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation** has announced development of a simple electronic method for monitoring jet engines in flight and on the ground. The monitor is said to warn of impending trouble by indicating when unusual "foreign" vibrations—caused by imbalance of rotating parts—are present and when "normal" engine vibration limits are being exceeded. The system weighs from 12 to 34 lbs. depending upon the number of engines on the aircraft. Basic components of a typical four-engined system include a short 1/2 ATR rack with four amplifier modules, four indicators, one to four pickups per engine, a pickup switch and optional warning lights.

• **Systems Laboratories Corporation** has announced receipt of a prime contract from the Air Force in the field of "charting from advanced high-altitude reconnaissance systems." The classified project will be managed by Lewis Larmore, a specialist in infared and instrumentation who is in charge of his firm's experimental physics effort.

• **Thiokol Chemical Corporation** has announced that its new static testing facilities, capable of handling solid propellent rocket engines up to 12 ft. in diameter, is in operation at the firm's new Utah Division. The firm said its horizontal test stand is designed to resist a two-million-lb. load. Francis E. Klemm has joined the company's Sales Staff as Technical Sales Representative on polyurethane resins.

• **Union Carbide Corporation,** Linde Company division, has introduced an improved model of its Prest-O-Lite No. 420 Welding and Cutting Outfit reportedly capable of welding up to 3/8 in. and cutting up to 2 in.... James A. Krumhansl has been named Associated Director of the Parma Research Laboratories of National Carbon Company division.... Robert M. Briney has been appointed President of Haynes Stellite Company division.

Engineers at Solar Aircraft Company, San Diego, study a mockup of the firm's newest small gas-turbine engine, the "Mercury," designed for the Army and Navy to power a one-man helicopter. Solar says the 50-lb. turboshaft engine will produce 55 s.hp. and 12 lbs. of jet thrust on a 100°F. day. Military designation is YT-62.

• **United Aircraft Corporation,** Hamilton Standard Division, has announced a major reorganization of the engineering department in which a technical staff has been created to serve all sections of the division's expanding engineering activities. The staff becomes a part of the consolidated engineering function reporting to Chief Engineer Thomas B. Rhines. The division also announced that it is producing a compact air-conditioning system for the Lockheed F-104A that is said to cool and pressurize the cabin and electronic compartment, and defog the cockpit windshield and canopy. It is 38 by 14 by 8 in., weighs 47 lbs., and delivers 35 lbs. of air per min. to the cockpit.

• **Vertol Aircraft Corporation** has announced the formation of a subcontracts department as part of the firm's long-range corporate planning program. The firm also reports that the Swedish Navy has purchased four Model 44 helicopters.

• **Vickers Incorporated** has published a new bulletin, No. A-5216, describing hydraulic pumps and motors, motor-pumps and hydraulic packages miniaturized for missile applications. Copies may be had by writing the firm's Aero Hydraulic Division, P.O. Box 302, Detroit 32, Mich.

• **Western Gear Corporation,** Electro Products Division, has announced the design and manufacture of a new a.c. oil-filled gearhead motor said to meet requirements of MIL-M-17059 and MIL-S-901, Class AI shock. Designation is Model 142YK8BR55.

• **Westinghouse Electric Corporation** has published a new booklet (DB-52-250) listing physical properties, applications and shape availability of four wrought high-temperature alloys. Copies may be had by writing the firm at P.O. Box 2099, Pittsburgh 30, Pa. R. E. Peterson, Manager, Mechanics Department, Westinghouse Research Laboratories, has been elected to a 3-year term as Director of the ASTM.

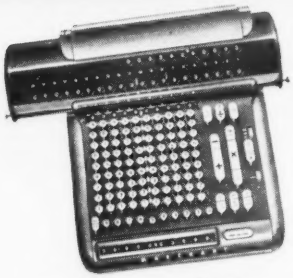
• **Weston Electric Instrument Corporation** has announced its Vamistor Manufacturing Division is now occupying expanded quarters in a new building at Union, N.J.

The drawing represents Thiokol Chemical Corporation's new static test facility for solid propellant rocket engines up to 12 ft. in diameter and for withstanding 2 million lbs. thrust. In operation at the firm's new Utah Division, Brigham City, the huge concrete bunker and horizontal test stand is larger than any other test facilities of Thiokol's divisions.

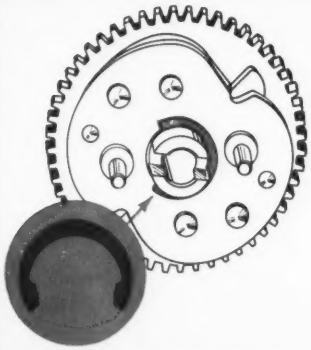
Attention Members!

All Members of the Institute are invited to submit material concerning their activities for publication in the news columns of the *Aeronautical Engineering Review.*

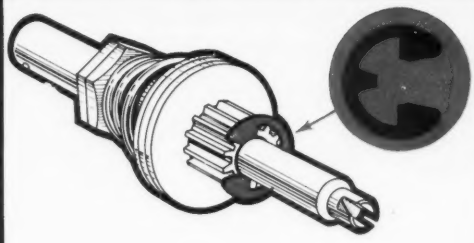
Waldes Truarc Rings speed assembly, facilitate maintenance, improve performance of new automatic calculator



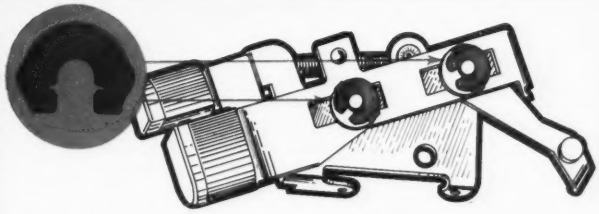
THE NEW MARCHANT DECI•MAGIC
automatic-decimals calculator made by Marchant Calculators, Inc., Oakland, California.



CRESCENT RING SPEEDS ASSEMBLY, DISASSEMBLY
Main clutch utilizes radially-installed series 5103 crescent ring for rapid assembly and disassembly. Ring's low protruding shoulder provides necessary clearance between ring and the two studs. The main clutch operates each time a Deci-Magic control key is depressed.



E-RING SECURES PARTS AGAINST SPRING THRUST. Slip clutch assembly uses Truarc series 5133 E-ring to hold parts on shaft. Functioning of the assembly is dependent upon the ring's ability to withstand thrust exerted by the heavy barrel spring.



LOCKING PRONG RINGS PERMIT SIMPLE DESIGN. Shift slide assembly uses two Truarc series 5139 bowed locking prong rings to lock the parts together in a sliding fit. Precise amount of spring tension prevents objectionable wobble and noise, permits the key to slide smoothly in operation. Easy radial assembly and disassembly of rings facilitates field maintenance and repair. Alternative construction would have required cut washer, spring washer and hairpin-type spring clip on each stud.

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IAS SECTIONS

Dayton Section

Neil Burgess, Manager, General Electric Company J-79 Project, told the story of the "J-79 Engine" at the June 20 meeting.

Future planning aimed at power plants for operational use in the 1958 to 1960 time period gave birth to the basic concept for the J-79 in 1952, he said. The concept resulted in a unique combination of design objectives—a very light engine offering superlative fuel economy for long-range cruising and very high thrust for combat use at twice the speed of sound. The engine was visualized in the 10,000-lb. thrust class.

Mr. Burgess said a decision was reached early in the program giving prime importance to test experience in the factory, in the wind tunnels, and in actual flight, and immediate correction of all difficulties was made. This was necessary to achieve successful and rapid development.

He said the engine passed its official Air Force Preliminary Flight Rating Test in 1955, several months ahead of contract schedule. It was then flown in a B-45 flying test bed and later in a modified Douglas XF4D at Edwards AFB.

Mr. Burgess described the J-79 as a single rotor, high pressure ratio engine with afterburner, incorporating variable stators in the front of the compressor. The compressor is made up of steel discs and does not have a central shaft. The turbine has three stages.

W. E. STANGER, *Secretary*

San Antonio Section

Landis Carr, Vice-President, Howard Aero Company Manufacturing Division, told the story of executive transport plane development at the June meeting.

Mr. Carr traced the development of his firm which has been completely rebuilding the old Lockheed PV-1 into the Super Ventura for the past 10 years.

He said, "Our biggest problem was to find an aircraft that had the growth potential that could be developed by our engineers." His company did an $8 million business last year, he said.

More than twelve companies and military units were represented at the meeting, according to Section Chairman J. J. Walden.

Major Robert A. Schneider, Treasurer and Membership Chairman, reported 18 new members had joined the Section or applied for membership as of June 18.

J. W. DRAPER, JR., *Secretary*

Texas Section

"Design and Testing of the Regulus Missile" was discussed by Sam Perry at the Daingerfield subsection's first regular meeting on May 28. Mr. Perry is Chief Engineer, Missile Projects, Chance Vought Aircraft, Inc.

The classified talk was supplemented with slides and a color film. Twenty-eight members and guests attended the meeting.

R. J. VOLLENZ

STUDENT BRANCHES

Oregon State College

Members of the Branch met on May 15 for the annual election of officers for the coming school year.

New officers elected were Chairman, Ronald W. Morcom; Vice-Chairman, Louis M. Reinkens; Secretary, Jack D. Foster; and Treasurer, Patrick H. Hall.

H. D. Christenson was named Faculty Adviser.

JACK D. FOSTER, *Secretary*

Parks College of Aeronautical Technology

Twenty-two members at the June 27 meeting elected a new slate of officers for the coming school year. New officers are Chairman, Jerry Meyer; Vice-Chairman, Terry Fitzgerald; Secretary, Gerald Chmielewski; Treasurer, Donald Groene; and Librarian, Jerry Beauchamp.

GERALD E. CHMIELEWSKI, *Secretary*

Tri-State College

The first meeting of the summer term was attended by 46 members and guests who saw a film, *Airpower of '56—A Report to the Nation.*

Highlights of the National Air Show and Bendix Trophy Race at Philadelphia in 1956 were shown.

▶ E. H. Shuette, Dow Chemical Company, spoke on "The New Look in Research" at the Branch's semiannual banquet May 23. He said that the new look is the trend toward freeing researchers from unnecessary paper work and red tape, leaving them with more time for pure research.

New officers elected for the summer term were Chairman, John Espy; Vice-

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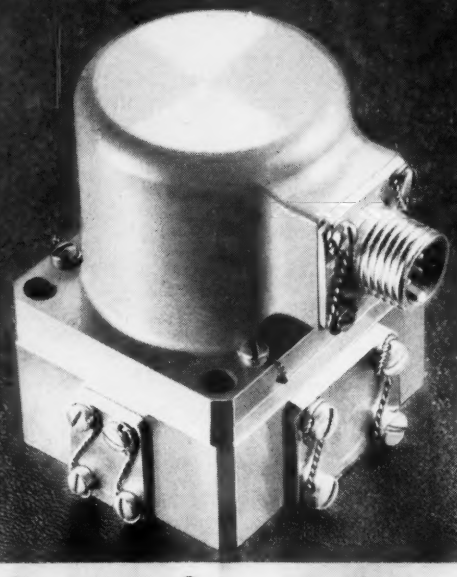

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Rated flow	0.12 to 5 gpm
Fluid	OS45-1 (or) MIL-O-5606
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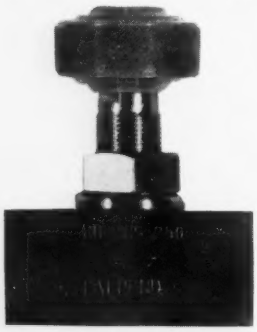
ROBBINS Leakproof Metering Valves



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2 E. 64th St. New York 21, N.Y.

Chairman, John Luther; Secretary, Donald Zurfluh; Treasurer, Ralph Hagloch; Council Representative, Jack Ebersol; and Reporter, William Berg.

The Branch Scholarship and Lecture Awards were presented to Richard F. Geide and Garrett W. Kruizenga, respectively.

▶ Members visited North American Aviation's Columbus, Ohio, plant on May 20. They toured the engineering and production sections of the facility, lunched in the plant cafeteria, and heard talks given by engineering section heads. The discussions covered work done at the plant, problems encountered, and a new engineer's specific duties. Two movies were shown at the end of the visit.

▶ Some 45 members went to the Armed Forces Day Air Show at Wright-Patterson AFB on May 19, but the show was rained out in the afternoon, and a visit to static displays at the Base Air Museum was substituted.

DONALD P. ZURFLUH, *Secretary*

U.S. Air Force Institute of Technology

Some 50 members and guests attended a joint meeting of the Branch and Pi Epsilon Gamma Honor Society on July 8 for the election of 1957–1958 officers.

New officers are Capt. Tipton F. Mott-Smith, Chairman; Lt. Frank R. Anderton, Jr., Vice-Chairman; Capt. David W. Hall, Secretary; and Lt. David H. Owen, Jr., Program Chairman.

Besides the election, a movie, *ARDC Staff Film Report No. 37*, was shown. The film was classified.

LT. ALIDORE A. JANCAUSKAS
Secretary

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Bruckmann, Bruno W., M.S. in M.E., Mgr., Engine Proj., General Electric Co. (Cincinnati).

Buckner, Howard A., Jr., B.S. in M.E. Sr. Engrg. Specialist, AiResearch Manufacturing Co. of Arizona.

Fowler, Roy G., B.S. in Physics, Design Specialist, Convair Div. (San Diego), General Dynamics Corp.

Krutter, Harry, Ph.D. in Physics, Chief Scientist, NADC (Johnsville).

Krzyczkowski, Stanislaw, M.E., Tech. Dir., International Air Transport Assn.

Mathews, Warren E., Ph.D. in Physics, Head, Advanced Planning Staff, Hughes Aircraft Co.

Raber, William H., B.S. in Ae.E., Supt., Missions Research Div., NADC (Johnsville).

van der Maas, H. J., Dr. of Tech. Sciences, Prof. of Aero. and Head, Dept. of Aero. Engrg., Delft Technical Univ.

Vandrey, Julius F., Design Engr., Aerophysics Research, The Martin Co.

Yoshihara, Hideo, Ph.D. in Ae.E., Chief, Theoretical Aerodynamics, Convair Div. (San Diego), General Dynamics Corp.

Transferred to Associate Fellow Grade

Beck, Niels J., Ph.D. in M.E., Chief, Propulsion Sect., Douglas Aircraft Co., Inc. (Long Beach).

Coleman, Thomas F., M.S. in Ae.E., Sr. Staff Engr., Systems Devel. Lab., Hughes Aircraft Co.

Crawford, Herbert R., B.S. in M.E., Dir. of Flight Test, Grumman Aircraft Engineering Corp.

Gatewood, Buford E., Ph.D. in Applied Math., Research Coordinator and Prof., Air Force Institute of Technology (Wright-Patterson AFB).

Görtler, Henry, Ph.D. in Pure and Applied Math. and Physics, Prof. and Dir. of Institute for Applied Math., Univ. of Freiburg, Germany.

Hamilton, William T., M.S. in Ae.E., Staff Engr., Aerodynamics, Boeing Airplane Co. (Seattle).

Helmbold, Heinrich B., Research Scientist, Fairchild Aircraft Div., Fairchild Engine & Airplane Corp. (Hagerstown).

Huester, Harry J., Comdr., USNR; Aero. Engrg. Officer, Overhaul & Repair Dept., NAS (Jacksonville).

Jones, Clyde B., B.S. in M.E., Dir. of Engrg., Aircraft Div., Hughes Tool Co.

Kaufman, Harold, B.S. in M.E., Head, Aircraft Systems, Air Warfare Research Dept., NADC (Johnsville).

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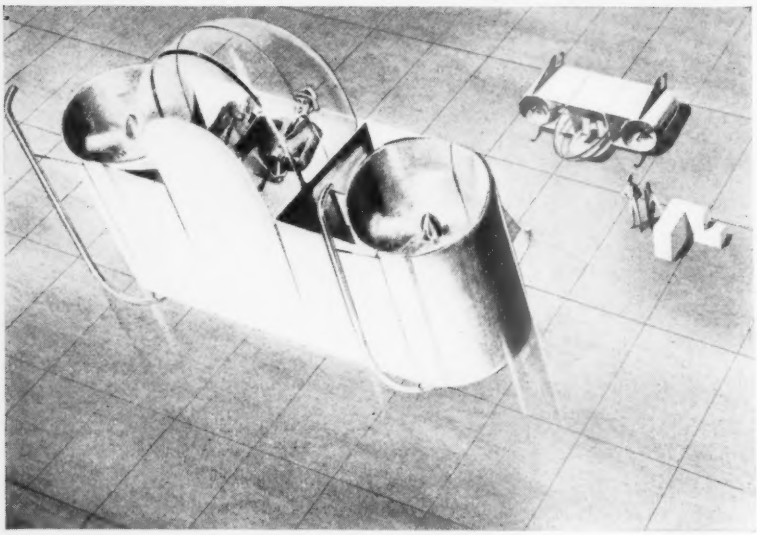

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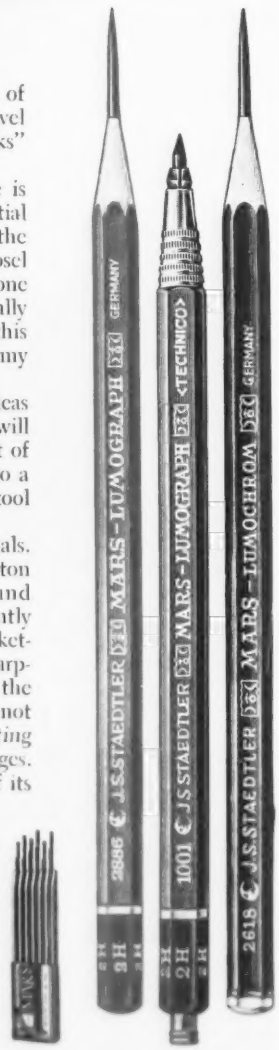

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ROCKET POWER PROGRESS REPORT

Servicing Rocket Engines

Part I: Know-How

by Fred Barker

Supervisor of the Product Service Department at Reaction Motors, Inc., Mr. Barker coordinates the activities which keep rocket engines on their good behavior. A graduate of New York University, with a B.S. in M.E., he has had diverse experience in engineering—including test, manufacturing liaison and customer service liaison. Mr. Barker joined RMI in 1949.

"Know-how" in any business is the result of thorough training and experience on specific products. RMI Product Service Department personnel get a complete grounding on their products right from the development stages through field installation and operation. The know-how thus attained is turned into a direct benefit for all RMI customers.

Key service engineers and service representatives join a project during early development, work actively with Engineering, Component Development, Assembly, Test and Inspection Departments. Mock-ups are reviewed from the standpoint of service—i.e., whether proper consideration has been given installation, accessibility and serviceability of components and the overall powerplants.

When a project is ready to move into the field, these same key men act as instructors, conducting training programs to impart their accumulated knowledge to customer personnel and other service representatives. With our ROR powerplant (rocket-on-rotor for helicopters), for instance, Sikorsky, Navy and Marine Corps personnel attended training programs at RMI and in the field. Scope of these programs covered the rocket powerplant, its installation and operation in the Sikorsky HRS helicopter, and the use, transfer and storage of the hydrogen peroxide propellant. Once ROR settled into operations at the Marine Corps Air Station, Quantico, Virginia, the service representative's know-how assumed a stand-by character. Training programs were repeated or amplified only as required by personnel changes or powerplant modifications.

Safety is a major item in each RMI representative's assignment, because safe use of the powerplant and safe handling of propellants are of paramount importance. Safety is improved by service representatives through on-the-spot lectures and training programs, whereby procedures and policies are outlined and integrated into the activities routine. Again, at Quantico, an admirable safety record has been achieved and maintained in just this fashion. There, over the past few years, our service representative has assisted the Marines in safely utilizing the ROR powerplant and the hydrogen peroxide fuel for their HRS helicopters. The result is found in the simplicity of powerplant operations, peroxide handling and storage area procedures, and in the attainment of a "no personnel injured" safety record.

Obviously, know-how is of importance in a clutch situation. Wisely applied, it leads to the right decision and the proper corrective action on the scene of a problem. The recently launched Glenn L. Martin No. 13 Viking missile provides a case in point. Pre-static firing inspection revealed discrepancies in some components of our 20,000-pound thrust rocket engine. Normal field maintenance sufficed for all but one difficulty: a valve seat and poppet, scored by foreign material, required lapping to meet leakage specifications—but no lapping compound was on hand. Our service representative used common household cleanser, lapped the poppet and seat to within leakage specifications, and the program moved on with only minor delay. This difficulty remained minor only because prompt and proper handling prevented development of a major program obstacle. Immediate action was required; immediate action was taken.

In Part II, we shall examine the function of the service engineer and service representative in various areas of Product Improvement.

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If you desire one or more reprints of Mr. Barker's article, or would like to receive further information about employment at RMI, write to our Information Services Coordinator, Reaction Motors, Inc., 22 Ford Road, Denville, N. J.

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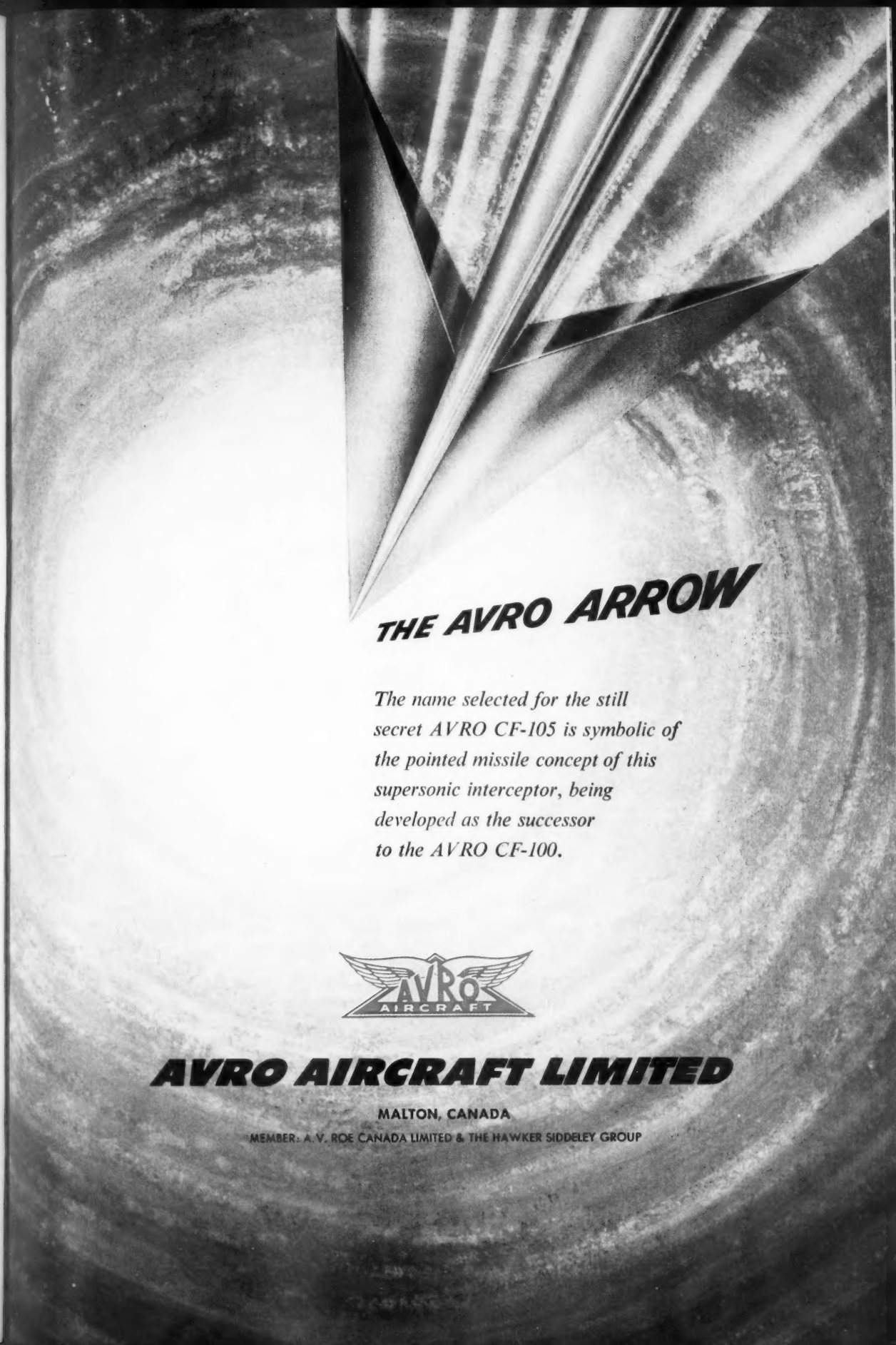
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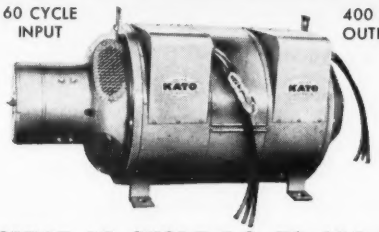

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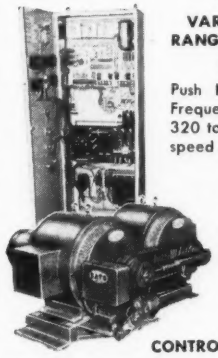

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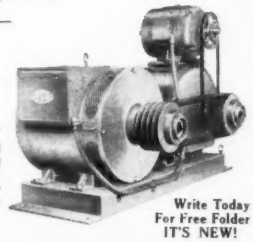

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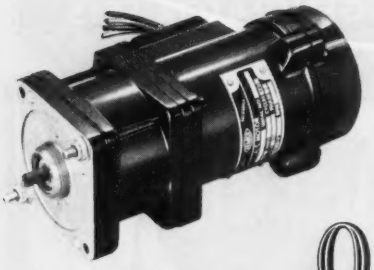

Type: C-1874 400 cycle 3 phase AC Motor and Clutch. **Weight:** 4.5 lbs. **Voltage:** 200 volts. **Output:** 650 watts. **Intermittent duty:** 12,000 rpm. **Meets Military Specification** MIL-M-7969A (ASG).

Type: D-638 400 cycle AC Motor. **Weight:** 17.5 lbs. **Voltage:** 200 AC, 20 amps at 6.5 hp. **Duty cycle:** 3.0 seconds at 6.5 hp, 15.0 seconds at 1.5 hp. **Maximum capacity:** 6.5 hp. **Continuous rating:** 5 hp at 2300 rpm, 15.8 amps, 200 volts. **Meets Military Spec.** MIL-M-7969A (ASG).

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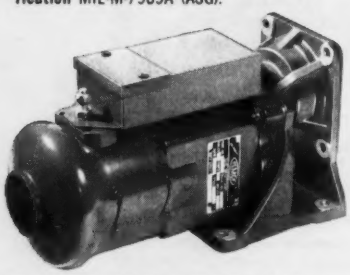
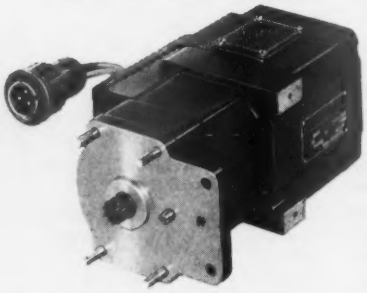


Type: D-751 DC Motor. **Weight:** 20 lbs. **Duty Cycle:** 5.2 hp at 2100 rpm (intermittent) on 26 volts DC; 3.5 hp at 2200 rpm (continuous) on 26 volts DC. **Meets Military Specification** MIL-M-8609.

Type: D-800 400 cycle 3 phase AC Motor. **Weight:** 8.75 lbs. **Voltage:** 208 volts. **Horsepower:** 2.5 hp. **Continuous Duty:** 11,300 rpm; Equipped with thermal protector. **Meets Military Specification** MIL-M-7969A (ASG).

Type: D-899 400 cycle 3 phase AC Motor. **Weight:** 11.25 lbs. **Volts:** 200 volts. **Load:** 2.75 hp continuous output. **RPM:** 3140 rpm output at gear box. **Power factor:** 83%. **Overall efficiency:** 76% for entire unit. **Meets Military Specification** MIL-M-7969A (ASG).

Type: D-932 DC Motor. **Weight:** With radio noise filter—13 lbs., without same—12.4 lbs. **Terminal voltage:** 27.5 DC plus or minus 1.5 volts. **Load:** From .5 hp minimum to 2.6 hp maximum. **Speed:** Continuous at 12,000 rpm, plus or minus .005%. **Speed Control:** By frequency regulator supplying control field. **Meets Military Specification** MIL-M-8609 (ASG).



Type: D-927 DC Motor. **Weight:** 7.25 lbs. with 2-circuit noise filter for ungrounded systems. **Weight of filter:** 1 lb. **Terminal voltage:** 27 volts, 18 amps. **Load:** 0.5 hp. **Speed:** Continuous at 9900 rpm. **Meets Military Specification** MIL-8609.

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Acoustics, Sound, & Noise

Noise—Some Implications for Aviation. K. K. Neely. *CAI Annual Gen. Meeting, Ottawa, May 27, 28, 1957, Preprint 7/8.* 10 pp. Members, $0.35; nonmembers, $0.70. Outline of suggestions to aid airport operators in attenuating and controlling high-intensity noise.

Jet Noise. Thomas M. Love. *Skyways*, June, 1957, pp. 10, 11, 36. Discussion of the effects of noise on human beings and the possible methods for reducing noise in and about airports.

Noise Research in the United Kingdom. E. J. Richards. *CAI Annual Gen. Meeting, Ottawa, May 27, 28, 1957, Preprint 7/7.* 25 pp. 48 refs. Members, $1.00; nonmembers, $2.00. Discussion covering the basic problem, the study of jet noise at the source, the suppression of jet noise, the effect of noise on structures, boundary-layer noise, and propeller and helicopter noise.

The Distortion and Interaction of Acoustic Waves of Finite Amplitude in a Viscous Medium. G. D. Mikhailov. *Soviet Physics - Doklady*, July-Aug., 1956, pp. 409–413. Translation. Phenomenological treatment of the propagation and interaction of waves to predict the spatial-intensity maximum both for the harmonics and the combination waves. It is shown that the positions of maxima for a given frequency are determined by the viscosity of the medium.

Noise Transmission from Boundary Layer Pressure Fluctuations. Robert H. Kraichnan. *USAF WADC TN 56-263 [AD 110523]*, Mar., 1956. 55 pp. 15 refs. Analysis of noise spectra radiated by the vibration of thin, stiff, flat plates under the action of turbulent boundary-layer pressure fluctuations. The transmitted radiation investigated arises from the streamwise convection of quasi-static pressure fluctuations by the steady flow, and is critically influenced by the dispersive character of transverse wave propagation.

Aerodynamics

Contribution of New Concepts in Aerodynamics to Executive Aircraft. August Raspet. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 741.* 14 pp. 11 refs. Members, $0.35; nonmembers, $0.75. Application of lift augmentation and a ducted pusher propeller to the executive aircraft.

Aerothermodynamics

Into the Fire. Maury Sulkin. *Skyline*, Summer, 1957, pp. 30–33. Basic discussion of aerothermodynamic problems encountered in the super- and hypersonic regions.

Stagnation Point Heat Transfer in Dissociated Air Flow. J. A. Fay, F. R. Riddell, and N. H. Kemp. *Jet Propulsion*, June, 1957, pp. 672–674. 10 refs. ARDC-sponsored derivation of an exact solution which represents a relation between the heat-transfer rate and the gas properties, whatever they may be.

Boundary Layer

Laminar Boundary Layer with Nonadiabatic Rotational Free Stream. Franklin D. Hains. *J. Aero. Sci.*, Aug., 1957, pp. 623, 624. Method for solving the flow over a flat plate with heat conduction and transfer of momentum into the boundary layer from the external flow.

Prediction of Turbulent Boundary-Layer Separation. James M. Robertson. *J. Aero. Sci.*, Aug., 1957, pp. 631, 632. 12 refs. Analytical method due to Ross which leads to qualitative indications regarding the occurrence of separation in two-dimensional boundary layers subjected to adverse pressure gradients. A separate form parameter D is employed to differentiate the outer flow from the inner flow. The effect of surface roughness is included in the analysis.

Comments on Some Recent Calculations Relating to the Laminar Boundary-Layer with Discontinuously Distributed Suction. W. S. Coleman. *J. RAeS*, May, 1957, pp. 359–361. Discussion of Lachmann's method of relating the velocity profile immediately downstream of a slot to that just in front of it.

Design Considerations in the Use of Powered Augmented Lift Systems. W. T. Hamilton. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 745.* 7 pp. Members, $0.35; nonmembers, $0.75. Presentation of data to show that for subsonic, long range aircraft having jet-engine sizes matched for maximum cruise efficiency, little can be gained from boundary-layer control or jet flaps. Advantages can be accrued for shorter field-length operations where larger thrust-to-weight ratios are required.

Fluid Mechanics & Aerodynamic Theory

Special Issue: Fluid Mechanics in Chemical Engineering. *Ind. & Eng. Chem.*, June, 1957, pp. 947–968, 970–977, 985. 83 refs. *Partial Contents*: Nonisothermal Flow of Viscous Non-Newtonian Fluids, R. E. Gee and J. B. Lyon. Simultaneous Heat and Mass Transfer in Free Convection, W. G. Mathers, A. J. Madden, Jr., and Edgar L. Piret. Chemical Reactions in a Water Tunnel, K. M. Kiser and H. E. Hoelscher. Static Pressure Distribution in the Free Turbulent Jet, David R. Miller and Edward W. Comings.

Hydrodynamic Problems Involving Large Fluid Distortions. Francis H. Harlow. *J. Assoc. Comp. Mach.*, Apr., 1957, pp. 137–142. Description of an analytical solution method.

On the Exact Solution of Compressible Couette Flow with Mass Addition and Binary Diffusion. Nathan Ness. *J. Aero. Sci.*, Aug., 1957, pp. 626, 627. Solution in which velocity, enthalpy, and diffusion profiles are expressed in terms of simple integrals for the completely general variation of all fluid properties.

Nekotorye Issledovaniia Strui Vody, Vytekaiuschchei iz Sopla pod Davleniem do 2000 Atmosfer. L. F. Vereshchagin, A. A. Semerchan, and F. M. Filler. *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk*, Jan., 1957, pp. 57–60. In Russian. Investigation of a water stream issuing from a nozzle under a pressure of 2,000 atmospheres.

Experimental Studies of the Lift on Two Equal Circular Cylinders Placed Side by Side in a Uniform Stream at Low Reynolds Numbers. Sadatoshi Taneda. *Kyushu U., Rep. Res. Inst. Appl. Mech., No. 18*, 1957, pp. 31–67. Test results which show that each cylinder experiences a repulsive force, with the value of the lift coefficient decreasing monotonously as the Reynolds Number is increased. When the Reynolds Number is sufficiently small, the value of lift coefficient first increases and then decreases as the ratio of the distance between two cylinders to the diameters of the cylinder increases.

A New Air for Engineers. Joseph G. Logan, Jr. *Res. Trends (Cornell Aero. Lab.)*, Spring, 1957, pp. 1–4. Discussion of flow phenomena as modified by hypersonic speeds, and the various effects that such real gas behavior exhibits.

A Note on the Sonic-Wedge Leading-Edge Approximation in Hypersonic Flow. M. H. Bertram and D. L. Baradell. *J. Aero. Sci.*, Aug., 1957, pp. 627–629. Re-examination of the validity of approximating the blunt leading edge on a flat plate by a sonic wedge.

Shock-Wave Curvature for Hypersonic Axisymmetric Flow. R. Sedney. *J. Aero. Sci.*, Aug., 1957, p. 630. Measurements of the ratio of the radii of curvature for the shock wave and the body. It is found that, from Mach Number 2.5 to 9, the ratio decreases from 1.7 to 1.2.

On the Bounds of the Thickness of a Steady Shock Wave. M. Z. v. Krzywoblocki. *Appl. Sci. Res., Sect. A*, No. 5-6, 1957, pp. 337–350. 35 refs. Analysis to determine if the use of higher-order Burnett terms from the solution of the Boltzmann equation using the von Mises approach improves the bounds of the thickness of steady shock. A negative result is obtained by following von Mises' reasoning.

Vortex-Ring Cascade and Turbulence Transition. Vivian O'Brien. *J. Aero. Sci.*, Aug., 1957, pp. 629, 630. Discussion of the significance of the effect of the cascade process on turbulence. It is felt that transition is due to the interaction of the vortex rings.

Internal Flow

Effects of Compressibility at Low Reynolds Number. Geoffrey Taylor and P. G. Saffman. *(IAS 25th Annual Meeting, New York, Jan. 28–31, 1957, Preprint 724.)* *J. Aero. Sci.*, Aug., 1957, pp. 553–562. Theoretical investigation for the effects of two possible errors in Reiner's experiment (for the flow between the rotor and the stator) which apparently established a non-Newtonian character of air flow, interpreted as a refutation of the Navier-Stokes equation.

Perdite di Carico Prodotte da Curve Isolate con Cambiamento di Direzione di 90° in Tubazioni a Sezione Circolare Costante in Moto Turbolento. Giuseppe Machne. *Tec. Italiana*, Mar., 1957, pp. 77–91. 42 refs. In Italian. Presentation of some experimental results on pressure loss in bent ducts, and derivation of a formula for practical applications, based on the concept of the equivalent length.

Graphical Estimation of Flow Through Orifices. E. J. Gabbay. *Aircraft Eng.*, June, 1957, pp. 175–177. Presentation of a generalized chart for estimating airflow

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Stability & Control

Stability and Control Problems Associated with Supersonic Aircraft. II. O. E. Michaelsen. *Can. Aero. J.*, June, 1957, pp. 178–184.

Extension of "An Aeroelastic Parameter for Estimation of the Effects of Flexibility on the Lateral Stability and Control of Aircraft." William P. Rodden. *J. Aero. Sci.*, Aug., 1957, pp. 624, 625.

Uravnoveshennost' Vozdushnykh Vintov. D. Nikolaev. *Grazhdanskaia Aviatsiia*, Apr., 1957, pp. 20–23. In Russian. Discussion of the balancing of air screws in terms of static, dynamic, and aerodynamic instability.

Effects of Horizontal-Tail Position and a Wing Leading-Edge Modification Consisting of a Full-Span Flap and a Partial-Span Chord-Extension on the Aerodynamic Characteristics in Pitch at High Subsonic Speeds of a Model with a 45° Sweptback Wing. William D. Morrison, Jr., and William J. Alford, Jr. *U.S., NACA TN 3952*, June, 1957. 37 pp.

Some Effects of Tail Height and Wing Plan Form on the Static Longitudinal Stability Characteristics of a Small-Scale Model at High Subsonic Speeds. Albert G. Few, Jr., and Thomas J. King, Jr. *U.S., NACA TN 3957*, May, 1957. 62 pp.

Wings & Airfoils

Effects of Leading-Edge Separation on Thin Wings in Two-Dimensional Incompressible Flow. L. F. Crabtree. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957, Preprint 659.*) *J. Aero. Sci.*, Aug., 1957, pp. 597–603.

Effet de Dérapage sur une Aile Delta. D. Vallée. *La Recherche Aéronautique*, Mar.–Apr., 1957, pp. 3–6. In French. Study of the sideslip of delta wings at zero incidence. The flow is assumed to be steady and supersonic and the wing inside the Mach cone. Lift, drag, and pitching and rolling moments are also calculated.

Über die Einflüsse der Pfeilung auf die aerodynamischen Eigenschaften der Tragflügel. A. Haerter. *Flugwehr und -Technik*, June, 1957, pp. 157–159. In German. Analysis of the effect of sweepback on the aerodynamic characteristics of airfoils.

Rule of Thumb Equation for Predicting Lifting-Surface-Theory Values of Lift. John DeYoung. *J. Aero. Sci.*, Aug., 1957, p. 629.

Aeroelasticity

Flutter of Rectangular Simply Supported Panels at High Supersonic Speeds. John M. Hedgepeth. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957, Preprint 713.*) *J. Aero. Sci.*, Aug., 1957, pp. 563–573, 586. 26 refs. Presentation of two panel-flutter analyses using a static approximation in conjunction with thin-plate theory. One analysis employs aerodynamic strip theory; the other, aerodynamic surface theory.

Formeln und Tabellen für ein den Hankel'schen Zylinderfunktionen verwandtes Integral. G. v. Gorup. *Max.-Planck-*

Inst. für Strömungsforschung, Mitteil. No. 15, 1957. 58 pp. DM 7. In German. Presentation of formulas and tables for the calculation of an integral related to Hankel's cylindrical function used in the problem of determining the air forces on an oscillating airfoil with a finite trailing-edge angle.

The Influence of the Curvature of an Originally Curved Bar on the Resonance Regions of Plane Form of Bending. Kazimierz Piszczek. *Arch. Mech. Stosowanej*, No. 2, 1957, pp. 155–189. Analysis to determine the resonance regions of the plane form of bending of a beam subjected to moments acting at the ends and having, in the nondeformed state, a constant curvature $1/R$ in the plane of maximum rigidity. Results are obtained for simply supported and built-in ends for several values of the radius R.

Unsteady-Lift Functions for Penetration of Traveling Gusts and Oblique Blast Waves. Franklin W. Diederich and Joseph A. Drischler, Jr. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957, Preprint 714.*) *Aero. Eng. Rev.*, Aug., 1957, pp. 47–51.

Investigation at Low Speeds of Deflectors and Spoilers as Gust Alleviators on a Model of the Bell X-5 Airplane with 35° Swept Wings and on a High-Aspect-Ratio 35° Swept-Wing–Fuselage Model. Delwin R. Croom and Jarrett K. Huffman. *U. S., NACA TN 4057*, June, 1957. 37 pp. Results indicate that deflector and spoiler-deflector types of controls can be designed to provide considerable gust alleviation for a swept-wing airplane while still maintaining stability and control.

A Wide - Frequency - Range Air - Jet Shaker. Robert W. Herr. *U. S., NACA TN 4060*, June 1957. 15 pp. Description of an air-jet shaker, some experimental data obtained with it, and a discussion of its possible uses and limitations.

Flutter Theory Being Reevaluated for High Performance Flight. Irwin Stambler. *Av. Age*, June, 1957, pp. 98–102, 105 ff. Discussion of aeroelastic problems and testing methods for above Mach 1 flight.

The Application of Rocket Sled Techniques to Flutter Testing. W. R. Laildlaw and V. L. Beals, Jr. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957, Preprint 666.*) *Aero. Eng. Rev.*, Aug., 1957, pp. 58–62, 77.

Aeronautics, General

Special Issue: European Aviation Development Progress. *Av. Age*, June, 1957, pp. 16–55. *Partial Contents:* Outlook for European Aviation Progress, Randolph Hawthorne. Government Deals Hard Blow at British Aviation, Denis Desoutter. French Aircraft Industry Now a Major Industrial Power, Robert Roux. Italy's High Quality Aircraft Industry Needs European Market, Vico F. Rosaspina. Close Cooperation Marks Dutch and Belgian Aircraft Industries, Hans Kosman. Aircraft Industry Backstops Swiss Defense, Walter P. Moser. Strong Air Force Keeps Swedish Aircraft Industry Busy. German Aircraft Industry is Making Steady Comeback.

Aeronautical Research in the Netherlands. H. J. Van Der Maas. *J. RAeS*, May, 1957, pp. 295–329; Discussion, pp. 329–334. 93 refs. Review of the organization, equipment, and current research projects at the NLL and the Delft Technical University.

Executive Aircraft for Business and Military. J. W. Sessums, Jr. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 739.* 9 pp. Members, $0.35; nonmembers, $0.75. Review of USAF policies that led to requirements for an executive-type aircraft, and discussion of the need for private development of such an aircraft.

Engineering Approach to Business Aircraft. Ralph M. Harmon. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 740.* 5 pp. Members, $0.35; nonmembers, $0.75. Human and economic considerations in designing a business executive aircraft.

L'Aviation Française, ses Progrès, ses Problèmes Techniques. M. J. Jarry. *Tech. et Sci. Aéronautiques*, No. 2, 1957, pp. 49–66. In French. Discussion of French developments in the aviation field, of the problems involved, and of the progress achieved. Includes description of different aircraft and engine types.

Air Transportation

Airline Technical Requirements Planning. Ray D. Kelly. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 751.* 9 pp. Members, $0.35; nonmembers, $0.75. Review of the technical studies made by United Air Lines in preparation for buying and operating jet air liners.

Europe and the U. S. A. Compared. *The Aeroplane*, June 7, 1957, pp. 806–808. Abridged. Comparison of the development in air transport in Europe and in the United States. Evaluation is made in terms of the general conditions affecting the development of air transport, the quality of service offered to the market, and the efficiency of the operation.

Around the World in 40 Hours. Marvin Miles. *New Frontiers*, Spring, 1957, pp. 3–7. Discussion of jet airliners, highlighting their advantages over present transport aircraft and the possible reaction of the public to their introduction. Six leading turbine-powered aircraft are compared as to type, payload, cruising speed, operational altitude, gross weight, and range in miles.

The Economics of Speed; An Examination of the Future Roles of Jet and Turbo-Prop Transport Aircraft. Appendix A—**A Short History of the Aircraft Gas Turbine.** Appendix B—**Method Used to Derive Comparable Hypothetical Jet and Turbo-Prop Transports.** Appendix C—**B.E.A. Method of Estimating Aircraft Costs.** Lord Douglas of Kirtleside. *J. Inst. Transp.*, May, 1957, pp. 115–131.

Airplane Design

Fiat G. 91, U. S. Inspired Italian Design, Girds for NATO Trials. David A. Anderton. *Av. Week*, June 10, 1957, pp. 50–55, 58–60 ff. Developmental history, design, and performance characteristics of the NATO light fighter.

Upside-Down Tiger. *The Aeroplane*, June 7, 1957, p. 826. Description of the modification of the Tiger Moth aircraft to provide it with satisfactory inverted-flight characteristics.

SO-9050 Trident II. *Avia Vliegwereld*, May 23, 1957, pp. 280, 281, cutaway drawing. In Dutch. Design and description of the SO-9050 Trident II aircraft.

The Philosophy of Lightweight Design. G. Gabrielli. *The Aeroplane*, May 31, 1957, pp. 771, 772. Discussion of tire-inflation pressures and the minimum economic size of an order as they affect a light tactical fighter.

Miles' Jet Lightweight. *The Aeroplane*, May 24, 1957, pp. 725, 726, cutaway drawing.

Thunderchief—Republic Aviation's Supersonic Fighter/Bomber. *Flight*, May 31, 1957, p. 724.

Comet 4B Postscript and Further Thoughts on Jet v Turboprop Economics. J. M. Ramsden. *Flight*, May 31, 1957, p. 749.

Les Nouveaux Avions Commerciaux Américains à Réaction. G. Bruner. *Docaéro*, May, 1957, pp. 19–34. In French. Presentation of general characteristics, design specifications, and performance data on jet transport aircraft such as Boeing 707, Douglas DC8, Douglas DC9, and Convair 880 "Golden Arrow."

The Continental Comet—A New Version for Greater Profitability. *de Havilland Gazette*, June, 1957, pp. 110–112. Performance and interior design details of Comet 4B, designed to compete economically with turboprops in route stages of 300–2,000 miles.

The Research Airplane—Past, Present, and Future. W. C. Williams and H. M. Drake. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 750.* 15 pp. Members, $0.35; nonmembers, $0.75. Discussion of the history of research aircraft and the different problems which they have encountered.

Propjet and Turbojet Business Aircraft. W. H. Arata, Jr. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 742.* 27 pp. Members, $0.65; nonmembers, $1.00. Discussion of some of the major problems that an airframe manufacturer must consider in the development of high-speed business transports. These problems include determining aircraft market needs, formalizing the design from customer requirements, and operating procedures and economics.

Over Ten Miles a Minute with 172 Passengers. *Handley-Page Bul.*, Summer, 1957, pp. 14–16. Design and performance characteristics of a passenger version of the Handley-Page "Victor" bomber.

New Dart Herald Cruises at 275 m. p. h. *Handley-Page Bul.*, Summer, 1957, pp. 5, 6. Design and performance characteristics of a turboprop version of the Handley-Page "Herald."

Das schwedische Trainingsflugzeug Saab 91 "Safir." Alfred Aepli. *Flugwehr und -Technik*, June, 1957, pp. 159, 160. In German. Description of the Swedish trainer Saab 91 "Safir" aircraft.

De Fokker F 27 "Friendship" in de Definitieve Produktie - Uitvoering. *Avia Vliegwereld*, June 6, 1957, pp. 320, 321, cutaway drawing. In Dutch. Design and description of the Fokker F 27 "Friendship" aircraft.

Les Avions Légers de Combat Français. R. de Narbonne. *Air Revue*, May, 1957, pp. 235–237. In French. Description of French light fighter aircraft, with details of their design and performance.

Landing Gear

Recent Data on Tire Friction During Landing. Sidney A. Batterson. *U. S., NACA RM L57D19b*, June 7, 1957. 7 pp. Tests results showing the effect of forward speed and tire-inflation pressure on the coefficients of friction.

The Application of Ultra High Tensile Steel to the Design of a Modern Undercarriage. G. F. W. McCaffrey. *CAI Annual Gen. Meeting, Ottawa, May 27, 28, 1957, Preprint 7/2.* 17 pp. Members, $0.50; nonmembers, $1.00. Description of the undercarriage with details on steel specification and procurement, manufacturing and processing, heat treatment, plating, properties of ultra-high-tensile steel, and testing.

Landing Loads

A Summary of Ground-Loads Statistics. John R. Westfall, Benjamin Milwitzky, Norman S. Silsby, and Robert C. Dreher. *U. S., NACA TN 4008*, May, 1957. 15 pp. 17 refs. Review of NACA material on landing-impact, taxiing, and braking loads.

Windshields

Bird-Firing Gun Used in Development of "No-Hazard" Windshield for Electra. E. H. Spaulding. *(SAE Annual Meeting, Detroit, Jan. 14–18, 1957, Preprint 92.) SAE J.*, June, 1957, pp. 26, 27.

Transparent Cockpits Need High Optical Precision. L. F. Bonaz. *SAE J.*, June, 1957, pp. 63, 64. Discussion of optical distortion and its causes, and of production methods to improve the transparencies.

Airports

Neuartiges Flugzeugfangnetz für Flugplätze. Erhard Rossmann. *Flugwelt*, June, 1957, pp. 421, 422. In German. Description of a net equipment for stopping aircraft upon landing at airports.

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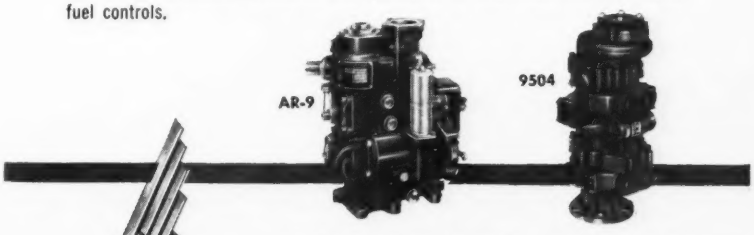

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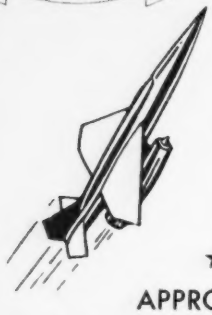

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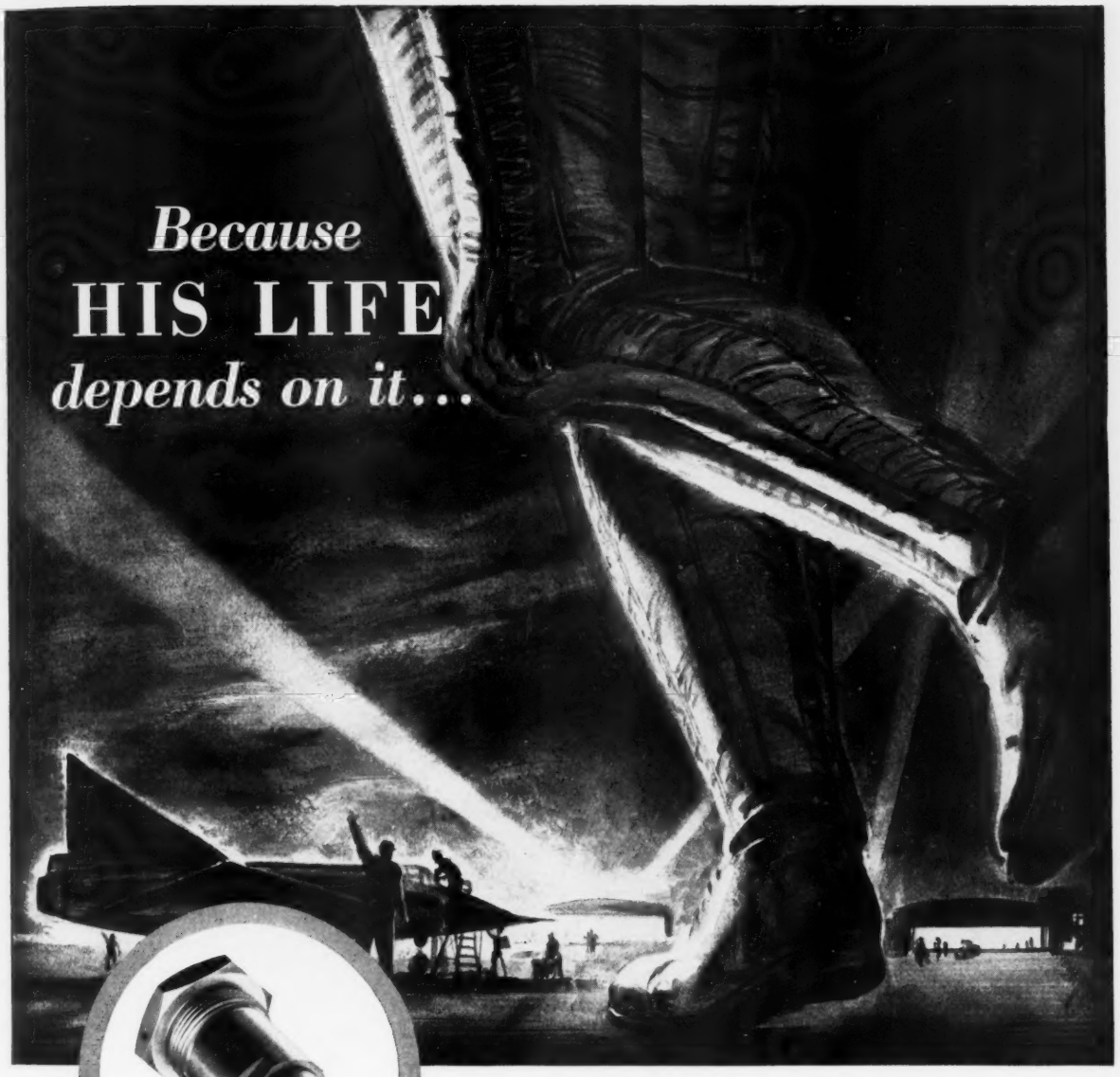

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822. USAF-Army-Navy-supported analyses of components and of the resulting component applications made by the staff of the Lincoln Laboratory over a period of several years, and description of the design method developed there. Includes a detailed illustrative example of a high-speed, vacuum-tube flipflop.

A High Input Impedance Transistor Circuit. Philip J. Anzalone. *Electronic Des.*, June 1, 1957, pp. 38–41. Method for increasing the obtainable input impedance orders of magnitude beyond that observed for conventional transistor circuits.

Junction-Transistor Bootstrap Linear-Sweep Circuits. K. P. P. Nambiar and A. R. Boothroyd. (*IEE Paper 2228 R.*) *Proc. IEE, Part B*, May, 1957, pp. 293–306. Description of circuits for which deviations from perfect sweep linearity of much less than one per cent are estimated to be possible. Includes description of a particularly precise monostable circuit and investigation of the limitations imposed on circuits by the frequency-dependent properties of the transistors.

Poles and Zeros Speed Circuit Analysis. W. A. Scism. *Electronic Ind. & Tele-Tech*, June, 1957, pp. 114, 115, 441, 444.

Communications

Experience with Single-Sideband Mobile Equipment. R. Richardson, O. Eness, and R. Dronsuth. *Proc. IRE*, June, 1957, pp. 823–829. 10 refs. Army-supported description of an experimental V.H.F. single-sideband equipment used for performance comparison with narrow-band FM equipment. Includes discussion of problems associated with transmitter design and power, pilot carrier recovery, sideband detection, a.g.c. response time, and ignition noise suppression.

"Big Talk" Links SAC's Bomber Forces. *Collins Signal*, Summer, 1957, pp. 4–7. Description of single-sideband (SSB) radio equipment used to monitor the B-52 round-the-world flight.

Construction Techniques

The Reliability Factor in Relay Applications. John Vetrano. *Auto. Control*, June, 1957, pp. 26, 27. Discussion in terms of designing to specifications, inspection, environmental testing, and reporting on field performance.

Cooling Packaged Electronic Equipment. II—Selecting the Method of Cooling. A. Donald Hay. *Electronic Des.*, June 1, 1957, pp. 48–51. Discussion of forced-air cooling, and its advantages and limitations. Also mentioned are direct liquid cooling and vaporization cooling.

Packaging Considerations with Semiconductors. W. H. Klippel. *Elec. Mfg.*, June, 1957, pp. 112–117, 374–382. Practical solutions to problems associated with miniaturization of electronic subassemblies. The solutions are based on computer design experience.

Electronic Tubes

A Study of Environmental Temperature and Pressure Effects on the Plate Dissipation Rating of Receiving Tubes. Appendix I—Maximum Bulb Temperature and Plate Temperature Confidence Limits for Electron Tube Type 5654/6AK5W. Bernhard M. Schmidt. *USAF WADC TR 53-433, Pt. 2 [AD 110553]*, Dec., 1955. 37 pp. Presentation of extrapolation curves based on experimental results obtained from two or three samples of specially constructed tubes, and derivation of an empirical method useful for the advance prediction of maximum bulb temperature of a receiving tube from knowledge of the total power input and the expected environmental temperature.

The Hyperbolic Field Tube, a Cathode Ray Tube for Multiplication in Analogue Computers. W. Schmidt. (*ZAP*, 1956, pp. 69–75.) *Gt. Brit., RAE Lib. Transl. 646*, Mar., 1957. 13 pp.

Magnetic Devices

Ferrites—1957. Lawrence G. Rubin. *Electronic Des.*, June 1, 1957, pp. 20–23. Discussion of composition and material properties, along with possible applications.

Ferrites at Microwaves. P. E. V. Allin. *Electronic Eng.*, June, 1957, pp. 292–296. Discussion of principles, applications, and performance of nonreciprocal microwave ferrite devices.

Nonmetallic Ferromagnetic Materials. II—Low Loss High Temperature Ferrites, John M. Blank. **III—Ferrite Single Crystals,** Aaron P. Griefer and Gerald G. Palmer. **IV—The NiO-Fe_2O_3 System,** Gerald G. Palmer and James P. Dietz. **V—Ferrite Delay Lines,** Gerald G. Palmer, Robert W. Johnston, Harold W. Katz, and Robert E. Schultz. **VI—Ferrite Measurements Program,** Robert E. Schultz and Harold W. Katz. **VIII—Loss Studies in Ferrites,** Nathan Schwartz and Aaron P. Greifer. *USAF WADC TR 56-274, Pts. 2, 3, 4, 5, 6, 8 [AD 110611; 110615; 110617]*, Dec. 15, 1955 (Jan., 1957). 24; 17; 22; 86; 93; 30 pp. 25 refs.

An Investigation of Some Barium Titanate Compositions for Transducer Applications. D. Schofield and R. F. Brown. *Can. J. Phys.*, May, 1957, pp. 594–607.

Networks

Design of Mixers Using Conductance Curves. K. A. Pullen, Jr. *Electronic Des.*, June 1, 1957, pp. 32–35.

A Network Theorem. E. Green. *Marconi Rev.*, 2nd Quart., 1957, pp. 35–38. Presentation of theory for a symmetrical network with equal resistance terminations. Discussion includes a general solution for networks having a maximally flat or Chebyshev type of response.

A 16kc/s Amplitude Modulator Employing Envelope Feedback. K. G. Corless. *Electronic Eng.*, June, 1957, pp. 287–290.

Avalanche Flow Line Analysis. Richard B. Hurley. *Electronic Ind. & Tele-Tech*, June, 1957, pp. 101, 102, 437, 438. Study to show how avalanche multiplication can be included in the equations of Evers and Moll and how flow-line diagrams may be extended in scope to cover avalanche.

Topological Analysis of Linear Nonreciprocal Networks. Samuel J. Mason. *Proc. IRE*, June, 1957, pp. 829–838. USAF-Army-Navy-supported re-examination of Kirchhoff and Maxwell's topological methods for the analysis of reciprocal branch networks in order to extend these methods to nonreciprocal networks and to keep the topological relationships as simple as possible. The theory developed is proved, and application of the techniques to practical circuit-analysis problems is illustrated.

Noise and Interference

Theory and Experiments on Shot Noise in Semiconductor Junction Diodes and Transistors. W. Guggenbuehl and M. J. O. Strutt. *Proc. IRE*, June, 1957, pp. 839–854. 27 refs. Presentation of a general theory for noise in the region of low-level injection currents as dependent on frequency, and experimental curves at high-level injection.

Noise in Negative Feedback Amplifiers. C. N. W. Litting. *Electronic & Radio Engr.*, June, 1957, pp. 219–223. Analysis of noise originating in the input circuit and other points in an amplifier. The effect of negative feedback under various conditions is considered, and it is concluded that under certain conditions a great improvement in signal-to-noise ratio may be obtained by using feedback.

Semiconductors

Visualizing Transistor Principles. Oscar E. Pierson. *Western Union Tech. Rev.*, July, 1957, pp. 100–110. Discussion of the physical principles behind transistor operations.

The High Current Limit for Semiconductor Junction Devices. Neville H. Fletcher. *Proc. IRE*, June, 1957, pp. 862–872. 26 refs. Derivation of equations relating carrier densities on either side of a forward-biased junction. These equations are applied to derive the forward characteristics of two diode types and to consider the dependence of emitter efficiency on current density for alloy junction transistors.

Theory of Isothermal Galvanomagnetic and Thermomagnetic Effects in Semiconductors. F. G. Bass and I. M. Tsidil'kovskii. (*Zhurnal Experimental'noi i Teoreticheskoi Fisiki*, Oct., 1956, pp. 672–683.) *Soviet Physics–JETP*, May, 1957, pp. 565–574. 10 refs. Translation. Consideration of the case of intermediate and strong magnetic fields for various types of interaction of the carriers with the crystal lattice. Includes determination of the features of the galvanometric and thermomagnetic effects that depend on the statistics and on the scattering law.

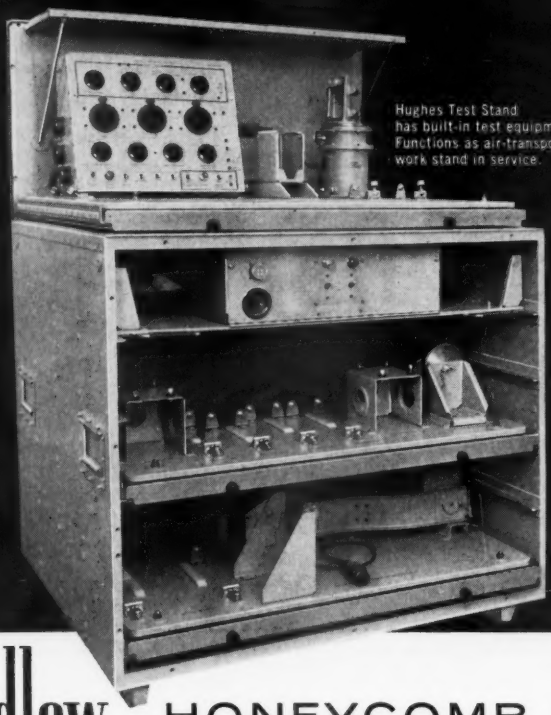
Point-Junction Transistors. W. Rosiński and J. Pułtorak. *Bul. Acad. Polonaise Sci.* (Warsaw), No. 2, 1957, pp. 95–98. Description of the design difficulties associated with the point-junction transistor, its advantages, and its characteristics.

Telemetry

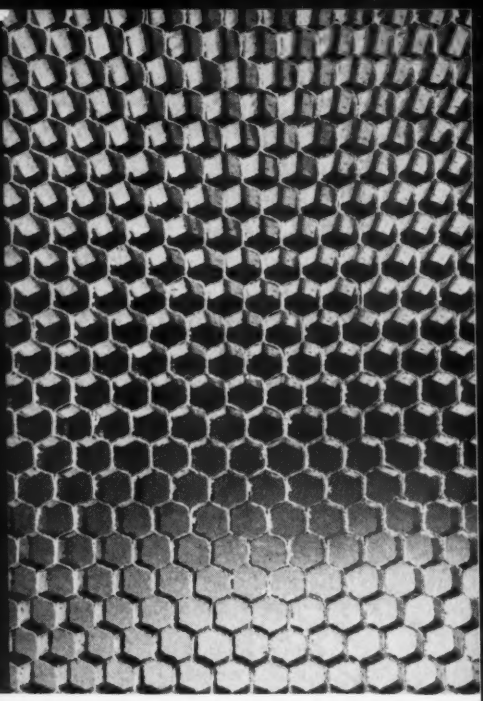
Redstone In-Flight Telemetering. Charles T. N. Paludan. *Missiles & Rockets*, June, 1957, pp. 126, 128. Discussion on four required measurements from the flight-test program, the type of gages used, and special design problems.

Staticheskoe Peredaiushchee Ustroistvo Chastotno-Impul'snoi Sistemy Teleizmereniia. A. M. Pshenichnikov. *Avtom. i Telemekh.*, May, 1957, pp. 445–448. In

(*Continued on page 149*)



Hughes Test Stand has built-in test equipment. Functions as air-transportable work stand in service.



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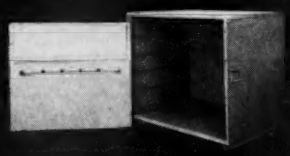
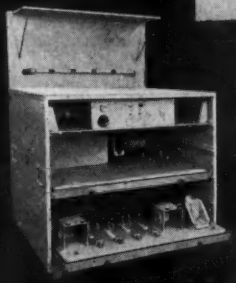
Front of Test Stand is removable: It may be attached, as shown, to rear of cabinet. Flip-out shelf is handy accessory feature during testing.

Hughes Aircraft Co. Test Stand is equipped with skids on bottom, and handles on sides for easy handling. Approximately 30" x 40", closed.





Sub-assemblies are mounted on racks, slide in and out.

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Armament control systems, radar systems, computer program equipment, and other types of electronic systems are easily tested and quickly serviced by use of these unique, air-transportable honeycomb panel test stands produced by Swedlow Plastics Company to the specifications of Hughes Aircraft Company.

Sides, bottom, and top are of Swedlow aluminum honeycomb material between sheet aluminum faces. Each cabinet contains sub-assemblies and the test equipment necessary for checking out the particular portion of the electronic system it houses. These sub-assemblies are mounted on racks that slide into the cabinet, and are kept ready as spares for instant replacement in the operating system whenever required.

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Swedlow aluminum honeycomb material is available in a variety of core designs, sizes, and thicknesses for applications such as Partition Panelling, Flooring, Stabilizers, Missile Fins, Tow Targets, Tail Assemblies, Ducting, Pressurized Tanks, Radar Vans, Microwave Reflectors, Electronic Gear Housings, Heat Exchangers, etc.

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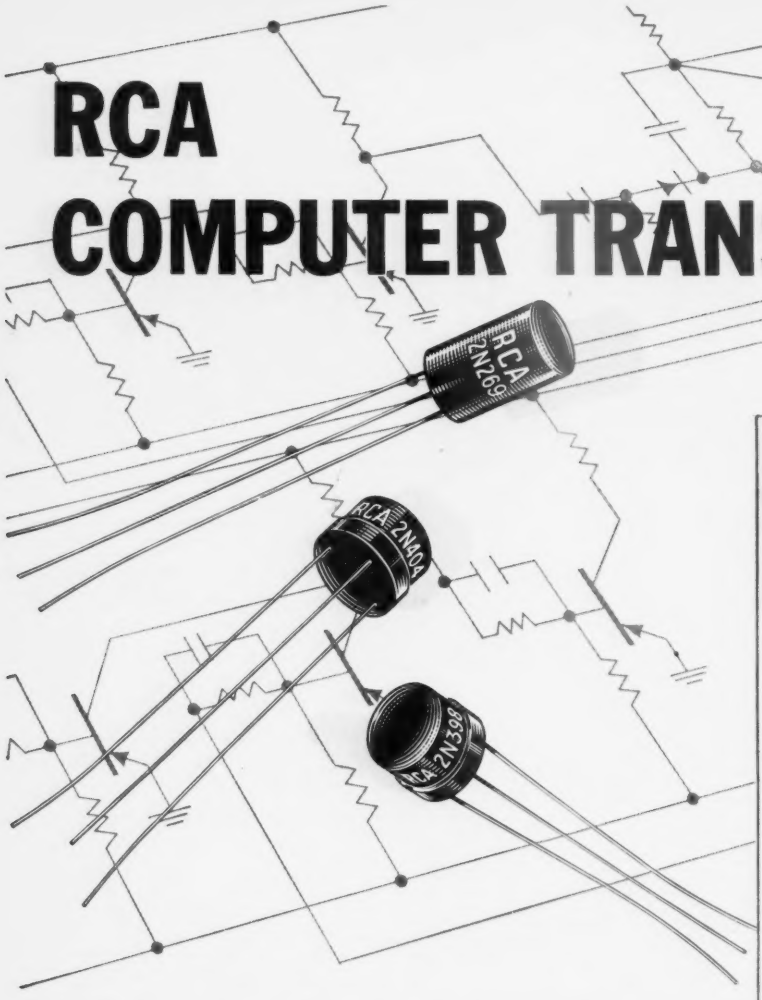

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RCA-2N404, RCA-2N269—feature a maximum collector-to-emitter saturation "bottoming" voltage of only 150 millivolts with a current gain of 30. This feature makes possible the design of stable "on" circuits and allows highly flexible design of digital equipment. Specification of Ico at 80°C as well as at 25°C permits the design of "off" circuits which are stable (absolute) *for wide variations in temperature.* A new method of controlling switching-time is achieved by controlling the maximum stored charge in the base region. Circuits using RCA-2N404 and -2N269 can thus be designed to have predictable switching speed and *complete unit-to-unit interchangeability.*

RCA-2N398—features an exceptionally high collector voltage rating which now permits the design of neon-indicator circuits where the transistor is capable of directly switching the total firing voltage of the indicator lamp. This simple circuit design provides for *improved system reliability.* The high collector voltage rating is also useful in the design of other high-voltage "on-off" control circuits such as relay pullers, incandescent lamp drivers, and direct indicating counters.

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- have high current gain
- provide reliable operation over wide temperature range
- have controlled stored charge

105-VOLT SWITCHING TRANSISTOR

RCA-2N398

- uses JETEC Size Group 30 Case designed for automation requirements
- improves system reliability
- simplifies neon-indicator

TECHNICAL DATA—RCA-2N404 and RCA-2N269

Max. Ratings	V_C	I_C	Collector Dissipation	Storage Temp.
	-25 volts	-100 ma	120 mw at 25°C 35 mw at 55°C 10 mw at 71°C	-65°C to +85°C

Characteristics* (at ambient temperature of 25°C unless otherwise specified)

	Typical Values	Range Values Min.	Range Values Max.
Collector Cutoff Current (V_C -12v, I_E 0)	-2μa	–	-5μa
Collector Cutoff Current (V_C 12v, I_E 0, T_A 80°C)	-45μa	–	-90μa
Collector-to-Emitter Saturation Voltage (I_B 0.4 ma, I_C 12 ma)	-100mv	–	-150mv
Alpha Cutoff Frequency (I_E 1.0 ma, V_C 6v)	12Mc	4Mc	
Stored Base Charge (I_C 10 ma, I_B 1.0 ma)	800 μμcoulombs	–	1400 μμcoulombs

TECHNICAL DATA—RCA-2N398

Max. Ratings	V_C	I_C	Collector Dissipation	Storage Temp.
	105 volts	100 ma	50 mw at 25°C 10 mw at 55°C	-65°C to +85°C

Characteristics* (at ambient temperature of 25°C unless otherwise specified)

	Typical Values	Range Values Min.	Range Values Max.
Collector Breakdown Voltage (I_C 50μa, I_E 0)	-150 volts	-105 volts	–
Collector-to-Emitter (Punch Through) Voltage (V_E 1v, I_E 0)	-150 volts	-105 volts	–
Collector Cutoff Current (V_C 2.5v, I_E 0)	-6μa	–	-14μa
DC Current Transfer Ratio (V_{CE} 0.35v, I_B 0.25 ma)	60	20	

*All voltage values are given with respect to the base, unless otherwise specified.

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INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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Volume 2, Number 9 September, 1957

ACOUSTICS, SOUND, & NOISE

THE TECHNICAL POSSIBILITIES OF REDUCING THE NOISE OF JET AIRCRAFT. E. J. Richards. Shell Av. News, May, 1957, pp. 19-24. Discussion starting from an explanation of the nature of jet noise in terms of its acoustic type of source (quadrupole) and the significant physical factors emerging from consideration of Lighthill's equation. The four basic means for reducing jet noise - a) reduction of the engine power, b) reduction of the jet exit velocity, c) modification of the jet shape and d) reorientation of the flight plan or ground test stands - are described and evaluated, and it is pointed out that present knowledge of noise-producing mechanism is such that it is possible, from a scientific point of view, to design devices capable of reducing noise in flight and on the ground to about the level prevailing before the introduction of jet airliners.

NOISE SURVEY OF A FULL-SCALE SUPERSONIC TURBINE-DRIVEN PROPELLER UNDER STATIC CONDITIONS. Max C. Kurbjun. US, NACA TN 4059, July, 1957. 20 pp. Measurements of overall sound-pressure levels and frequency spectra for the noise emitted at a 100-ft. radius from a full-scale, 7.2-ft.-diam., 3,500-r.p.m., three-blade supersonic propeller mounted on a turbine-driven aircraft. Results are compared with those obtained for a propeller of conventional design.

AERODYNAMIC MIXING IN A HIGH-INTENSITY STANDING-WAVE SOUND FIELD. W. R. Mickelsen and L. V. Baldwin. (ASA 2nd Internatl. Cong., Cambridge, Mass., June 17-23, 1956.) ASA J., Jan., 1957, pp. 46-49. Theoretical and experimental investigation of the effect of a transverse sound field on the temperature field downstream from a line source of heat. Results indicate that, in moderately intense sound fields, the temperature field is affected only in the time-mean sense; in intense sound fields, the heat wake is substantially deformed so that both the time-mean and instantaneous temperatures are considerably reduced.

SOME EXPERIMENTS RELATED TO THE NOISE FROM BOUNDARY LAYERS. H. H. Hubbard. (ASA 2nd Internatl. Cong., Cambridge, Mass., June 17-23, 1956.) ASA J., Mar., 1957, pp. 331-334. 21 refs. Correlation of wind-tunnel, rotating-disc, helicopter-rotor, and in-flight data to provide evidence regarding the mechanism of noise generation in the boundary layer and to show how the noise varies as a function of velocity, density, and surface roughness. The relative importance of the boundary-layer noise and the noise from the power plant in high-speed jet aircraft is discussed. Three aspects of the aerodynamic noise problem are considered: noise in the interior spaces of the aircraft, fluctuating surface pressures which may excite vibrations in the aircraft structure, and the noise radiated outward in space and away from the rotating aerodynamic surfaces.

NOISE TRANSMISSION FROM BOUNDARY LAYER PRESSURE FLUCTUATIONS. R. H. Kraichnan. ASA J., Jan., 1957, pp. 65-80. 16 refs. WADC-supported theoretical investigation of noise spectra radiated by the vibration of thin, stiff, flat plates under the action of turbulent boundary-layer pressure fluctuations. The transmitted radiation investigated arises from the streamwise convection of quasi-static pressure fluctuations by the steady flow and is critically influenced by the dispersive character of transverse wave propagation in the plates. Results are obtained for the dependence of transmission on Mach Number and on plate parameters including mass/unit area, size of independent plate sections, stiffness, and damping factors for various vibrational modes; and for the dependence of the transmitted spectrum shape on boundary-layer thickness. Several possible methods for reducing noise transmission are noted.

ON THE REFLECTION OF SOUND AT AN INTERFACE OF RELATIVE MOTION. J. W. Miles. ASA J., Feb., 1957, pp. 226-228. Theo-

retical investigation of the reflection of a plane wave of sound at an interface between two perfect fluids. Results indicate that previous predictions of Rudnick, Keller, and Franken and Ingard are in error due to improper boundary conditions, and that, in addition to the possibility of total reflection in some range of angles of incidence at all finite, relative speeds, there exists the possibility of a reflection coefficient exceeding unity for sufficiently high supersonic speeds; in particular, resonance may occur at one or more angles of incidence. Treatment includes discussion of the question of stability of the vortex sheet separating the two fluids.

SCATTERING OF SOUND BY SOUND. P. J. Westervelt. ASA J., Feb., 1957, pp. 199-203. WADC-supported analysis of the interactions of two or more sound waves passing through a common region in a perfect fluid. A source function is obtained for the lowest order scattering process which is quadratic in the primary field variables. This function is rewritten in a form which demonstrates that no scattered waves exist outside the region of interaction of two sound beams intersecting at right angles. The interfering effect of pseudo-sound, induced by radiation pressure, is suggested as an explanation for the results of Ingard and Pridmore-Brown.

ACOUSTIC RADIATION FROM A STATIONARY CYLINDER IN A FLUID STREAM (AEOLIAN TONES). B. Etkin, G. K. Korbacher, and R. T. Keefe. (ASA 2nd Internatl. Cong., Cambridge, Mass., June 17-23, 1956.) ASA J., Jan., 1957, pp. 30-36. 19 refs. Application to the flow past a circular cylinder of the equation for the radiated sound associated with body forces in a fluid. Qualitative verification of the theoretical results is obtained from subsonic wind-tunnel tests with the microphone located both inside and outside the tunnel. Overall sound-pressure levels and sound spectra are measured with various cylinders mounted in the test section. The sound field is found to be related to the oscillating lift and drag forces acting on the cylinder.

ACOUSTICAL CHARACTERISTICS OF OSCILLATING JET-EDGE SYSTEMS IN WATER. J. B. Brackenridge and W. L. Nyborg. ASA J., Apr., 1957, pp. 459--463. 15 refs. USAF-Navy-supported observations on the sound radiated by a self-excited underwater jet-edge system, in which a flat jet of water impinges on the sharp edge of a wedge or blade. Comparison is made between the sound (edge tones) generated when a rigid wedge is used and that when a fixed-free vibrating blade is employed. A characteristic kind of resonance is found, similar to that reported by others for analogous systems in air.

AERODYNAMICS

Aerothermodynamics

THE LAMINAR BOUNDARY LAYER WITH DISTRIBUTED HEAT SOURCES OR SINKS. P. L. Chambré. Appl. Sci. Res., Sect. A, No. 5-6, 1957, pp. 393-401. 15 refs. ONR-supported examination of the thermal boundary layer with distributed heat sources or sinks. The problem is reduced to the solution of an infinite system of ordinary linear differential equations. A basic connection between the problem considered and a certain class of three-dimensional boundary-layer flows is pointed out and utilized. The analysis is illustrated by an example which indicates pronounced effects on the temperature distribution due to the presence of sources or sinks.

THE EFFECT OF HEAT TRANSFER ON INTERACTIONS INVOLVING LAMINAR BOUNDARY LAYERS. K. N. C. Bray. Gt. Brit., ARC CP 339, 1957. 7 pp. Extension of Crocco and Lees' theory to account for heat-transfer effects in boundary-layer/shock-wave interactions and on boundary-layer separation. The Mach Number change which causes laminar-boundary-layer separation at large Reynolds Numbers is calculated as a function of wall temperature. A comparison is made between the effects of wall cooling and boundary-layer suction, as means of delaying separation. Suggestions are made for further application of the method.

Boundary Layer

AN EXPERIMENTAL INVESTIGATION OF LAMINAR BOUNDARY LAYER PROFILES IN A WEAK ADVERSE PRESSURE GRADIENT AT AN INCIDENT MACH NUMBER OF THREE. E. A. Racicot. UTIA Rep. 46, Mar., 1957. 34 pp. 25 refs. Pitot-tube tests in which the pressure gradient is obtained through the use of an inward-curving wall located immediately downstream of a Mach 3 supersonic nozzle. From this wall a family of coalescing wavelets cross the flow to be reflected at a flat plate which extends under the laminar boundary layer being tested. The profiles are compared with those predicted by Low's theory.

ON HARMONIC FUNCTIONS SATISFYING A MIXED BOUNDARY CONDITION WITH AN APPLICATION TO THE FLOW PAST A POROUS WALL. L. C. Woods. Appl. Sci. Res., Sect. A, No. 5-6, 1957, pp. 351-364. Solution for the general problem of determining an analytic function subject to a linear relation between its real and imaginary parts on a single boundary. The method used involves reducing the general problem to two simultaneous Dirichlet problems. The flow past an infinite wall, the porosity of which varies along its length, is calculated as a simple example, and the theory of an airfoil in a slotted tunnel is outlined.

AN INTEGRAL SOLUTION TO THE FLAT-PLATE LAMINAR BOUNDARY-LAYER FLOW EXISTING INSIDE AND AFTER EXPANSION WAVES AND AFTER SHOCK WAVES MOVING INTO QUIESCENT FLUID WITH PARTICULAR APPLICATION TO THE COMPLETE SHOCK-TUBE FLOW. R. L. Trimpi and N. B. Cohen. US, NACA TN 3944, June, 1957. 180 pp. 25 refs. Method for solving the two-dimensional unsteady laminar boundary layer existing at all points in an air-air shock tube utilizing an extension of the Kármán-Pohlhausen method. The Prandtl unsteady-boundary-layer equations are integrated normal to the surface bounding the flow, and

are transformed into a conical coordinate system. The resulting hyperbolic differential equations are integrated in closed form for flow behind shock waves and by numerical methods for the flow inside or following expansion waves. An integral technique is applied at the discontinuities existing at the trailing edge of the expansion fan and at isotropy discontinuities, in order that the characteristic solution may proceed across these discontinuities.

Control Surfaces

R. A. E. HIGH-SPEED WIND-TUNNEL TESTS OF THE TRAILING-EDGE CONTROLS ON A DELTA WING WITH 52-DEG SWEEPBACK. K. W. Newby. Gt. Brit., ARC R&M 2999, 1957. 22 pp. BIS, New York, $1.17. Test results which indicate that, for a C_L of 0.2 to 0.3, there is no appreciable reduction of effectiveness on any control below Mach 0.87. For Mach 0.94, all controls lose 50% of their effectiveness in pitch and roll. At higher incidence, reductions in effectiveness occur, particularly near Mach 0.87, but are mostly associated with the effects of control deflection at tip stalling. The pitching-moment characteristics show that cropping the pointed wing tip alleviates the tip stalling as expected.

Fluid Mechanics & Aerodynamic Theory

AN EXPERIMENTAL INVESTIGATION OF THE FLOW OVER SIMPLE TWO-DIMENSIONAL AND AXIAL SYMMETRIC BODIES AT HYPERSONIC SPEEDS. I. E. Vas, S. M. Bogdonoff, and A. G. Hammitt. Princeton U., Dept. Aero. Eng. Rep. 382 (USAF WADC TN 57-246) [AD 130826], June, 1957. Study to determine the inviscid shock shape and pressure distribution about thick two-dimensional and axially symmetric bodies. Details are obtained in the Princeton University helium hypersonic tunnel for flat and semicircular leading edges at Mach Numbers between 11 and 19. From the Schlieren pictures, the shock shape, detachment distance, and sonic point on the shock are found. Similiar pressure distributions are obtained for corresponding two-dimensional and axially symmetric bodies.

EXPERIMENTAL INVESTIGATIONS OF THE SUPERSONIC FLOW PAST A CIRCULAR CYLINDER BY THE MACH-ZEHNDER INTERFEROMETER. Shigeo Uchida and Michiru Yasuhara. J. Japan Soc. Aero. Eng., June, 1957, pp. 1-7. In Japanese. Description of a new method for adjusting fringes of the Mach-Sehnder interferometer by means of a pentaprism, a small quantity of mercury, and a telescope; and experimental investigation using an intermittent wind tunnel with a dryer. The pressure distribution along the surface of the cylinder and the streamline in the flow field are measured and compared with other observations and theoretical predictions.

INVISCID HYPERSONIC FLOW PAST BLUNT BODIES. S. H. Maslen and W. E. Moeckel. J. Aero. Sci., Sept., 1957, pp. 683 - 693. 11 refs. Presentation of two methods for calculating the flow field between a blunt body and the shock associated with it for the case of hypersonic flow. Real gas effects are taken into account in the solutions which consider only symmetric flows, i.e., symmetric bodies at zero incidence. One method consists in tracing successive stream tubes around the body and leads to iterations on the initially assumed position of the shock. The second is an integral method closely analagous to the Kármán-Pohlhausen procedure for boundary layer. A distinction is made between round- and flat-nosed bodies, and both cases are discussed. Includes calculation of a specific example corresponding to a re-entry missile situation.

ON THE FLOW OVER A FINITE WEDGE IN THE LOWER TRANSONIC REGION. Hideo Yoshihara. J. Aero. Sci., Sept., 1957, pp. 661-665. Analysis using the Kármán-Guderley transonic approximation. The hodograph transformation is made to linearize the flow differential equation and a wedge profile is selected in order to obtain, as far as possible, known boundaries in the hodograph plane. The complete solution is obtained by an iterative process in which all boundary and jump conditions are fulfilled. The location of the terminating shock wave is computed as well as the pressure distribution.

DRUCKVERTEILUNGEN ANGESTELLTER EBENER PLATTEN MIT ANGENÄHERTEM TOTWASSEREINFLUSS. G. Junclaus. ZFW, June, 1957, pp. 172--177. In German. Analysis of flow around a kinked plate with a linear increase in thickness from the kink. Velocity distribution and lift coeffient are given in complete terms. The calculations are applied to the flat plate with a split flap and to an approximate estimation of the wake boundaries and the loss of lift due to separation of the flow.

MEASUREMENTS OF PRESSURE FLUCTUATION IN THE WAKE OF CYLINDER. Yasujiro Kobashi. J. Phys. Soc. Japan, May, 1957, pp. 533-543. 14 refs. Experimental investigation using a new apparatus especially constructed for observing pressure fluctuations in turbulent flow. A condenser microphone is used as a transducer with a ratio discriminator in the construction, and the apparatus is calibrated by means of von Kármán vortices produced by a circular cylinder. The Helmholtz resonance and the loss in the pressure duct are compensated electrically by a band-rejection filter and a high-frequency booster. Using the apparatus alone, the overall frequency response of the pressure-measuring apparatus is made flat between 50 and 1,500 cps. In combination with a single rotary-type hot-wire anemometer, the apparatus is used to determine the intensity of the static-pressure fluctuation as well as the correlation between pressure and velocity fluctuation.

SOME INTEGRATED VOLUME PROPERTIES IN LINEARIZED FLOW AND THEIR CONNECTION WITH DRAG REDUCTION AT SUPERSONIC SPEEDS. Appendix A, B - VOLUME OF ADDITIONAL APPARENT MASS IN INCOMPRESSIBLE FLOW. Appendix C - SOME MEAN VALUE PROPERTIES OF TWO-DIMENSIONAL POTENTIAL FLOW. Appendix D - PSEUDO VOLUME FOR LIFT ELEMENT. Z. O. Bleviss. Douglas Rep. SM-19469, Feb.,

1956. 58 pp. Derivation of the basic formula relating the volume of a linearized body to the strength of the singularity distributions (elements of lift, side force, and volume) by means of continuity. Some integrated volume properties are proved and it is shown that the "average pseudo volume" for any given distribution of transverse forces and any specified streamwise axis is equal to a certain total body volume associated with the forces and the axis. Using Hayes' method, it is further shown that the spatial body volume density distributions due to transverse forces can be projected along Mach planes onto a specified streamwise axis to give the streamwise distribution along the axis for all angular positions on Hayes' distant control surface.

THE HYDRODYNAMIC STABILITY OF HELIUM II BETWEEN ROTATING CYLINDERS. I, II. S. Chandrasekhar and R. J. Donnelly. Royal Soc. (London) Proc. Ser. A, July 23, 1957, pp. 9--36. 12 refs. Theoretical investigation based on two assumptions regarding the mutual friction force, F, between the normal and the super-fluid components of the liquid. The hydrodynamic problem is solved for the case when the two cylinders (of radii R_1 and R_2) are rotated in the same direction and $(R_2-R_1) \ll 1/2\ (R_2+R_1)$. The characteristic-value problems resulting from the above study are solved correctly with respect to the boundary conditions which must be satisfied, and the nature and origin of the two types of instabilities occurring in this problem are further examined by considering the growth rate of small perturbations.

STUDIES ON THE HYPERSONIC FLOW USING A DOUBLE-DIAPHRAGM SHOCK TUBE. Fumio Tamaki and Kim Chul-Soo. J. Phys. Soc. Japan, May, 1957, pp. 550-555. 12 refs. Investigation of flow past elliptic-nosed plates using a flow of Mach Number 6.4 with a duration of 1 millisec., obtained by means of a specially devised shock tube having two partition diaphragms for generating a hypersonic flow free from air liquefaction. Axis ratios tested are 8, 1 (semicircular nose), and 0 (square-nose). Pressure distribution over the surface and head drag coefficient are determined by using a Mach-Zehnder interferometer.

INTERACTION OF A PLANE SHOCK AND OBLIQUE PLANE DISTURBANCES WITH SPECIAL REFERENCE TO ENTROPY WAVES. Che-Tyan Chang. J. Aero. Sci., Sept., 1957, pp. 675-682. 10 refs. Theoretical investigation, the results of which indicate that three kinds of disturbances exist in the perturbed field downstream of the shock, as a result of the interaction - an entropy mode, a vorticity mode, and a sound mode. It is shown that the nature of the sound wave generated depends on the orientation of the upstream disturbance: within certain orientations of this disturbance, the sound waves attenuate; beyond these orientations, they have constant amplitudes. Only when the downstream sound waves are attenuated does a phase shift occur in the entropy disturbance across the shock. Includes an illustrative example for the interaction between a plane normal shock and a sinusoidal entropy wave.

INTERACTION OF A SHOCK WAVE WITH A WIRE SCREEN. W. J. Franks. UTIA TN 13, May, 1957. 39 pp. 14 refs. Shock-tube investigation of the head-on collision of a plane shock wave with a wire-mesh screen in air. Interferometric and wave-speed camera studies enable the resulting wave system and detailed flow parameters to be determined for both nonchoked and choked flow through the screens. Nonchoked flow occurs at low-incident shock strength, and under these conditions the wave system consists of a reflected shock and a transmitted shock followed by a contact surface. With choked flow through the screens at higher incident shock strengths, the flow expands to supersonic speed behind the screen, and this supersonic region is terminated by a normal shock moving downstream. Simple one-dimensional models are proposed for nonchoked and choked cases on the basis of the observed wave systems.

ON THE MIXING THEORY OF CROCCO AND LEES AND ITS APPLICATION TO THE INTERACTION OF SHOCK WAVE AND LAMINAR BOUNDARY LAYER. I - GENERALS AND FORMULATION. Sin-I Cheng and K. N. C. Bray. Princeton U. Dept. Aero. Eng. Rep. 376 (AFOSR TN 57-283) [AD 132354], May, 1957. 66 pp. 20 refs. Evaluation of three semiempirical functions, in terms of which the Crocco-Lees theory treats the growth of a boundary layer. Three simple approximate solutions are developed for the equations involved in the application of the theory to laminar and turbulent layer shock-wave interactions. Then an exact solution is found numerically for a laminar boundary layer at a Mach Number of 2, an initial Reynolds Number of 10^5, and for five shock strengths giving deflection angles between 2^o and 4.2^o. The above procedure is applied to the problem of determining the critical strength of the shock wave required to produce incipient separation of a laminar boundary layer in a flat plate for the Reynolds Number and Mach Number range in which the laminar boundary layer usually occurs.

EXPERIMENTAL STUDIES ON THE STABILITY OF THE TRANSONIC FLOW PAST AIRFOILS. Fumio Tamaki. J. Phys. Soc. Japan, May, 1957, pp. 544-549. Measurements using a Mach-Zehnder interferometer and a rotating-drum camera to determine local flow fluctuations near an airfoil surface in the speed range near the critical Mach Number. Airfoils tested include the Tomotika-Tamada, the NACA-0012, and a 10%-thick elliptical cylinder. Results indicate that amplitude and frequency of oscillation appearing when the local sonic speed is exceeded on the surface depend on the profile shape. In the cases of the Tomotika-Tamada and the NACA-0012 airfoils, the oscillation is of small amplitude and high frequency when the maximum local Mach Number on the surface is not much above unity, and the time-mean pressure distribution on the surface is smooth and shows no appreciable distortion due to shock waves.

STATISTICAL STUDIES ON THE TURBULENT STATE OF MOTION. I - KINEMATICS. Hans Gebelein and Erik Svenson. USAF OSR TN 57-278 [AD 126539], Mar., 1957. 42 pp. Analysis to de-

termine the pressure, the local velocities with their dyadical products and their gradients, and the vorticity components. The investigation starts with the classical case of homogeneous and isotropic turbulence of an incompressible fluid. The three conditions are analyzed and it is shown how the results change when the suppositions are lessened. Anisotropic but homogeneous turbulence is treated in detail with particular attention to the velocity gradients and vorticities.

Internal Flow

SYSTEMATIC INVESTIGATIONS ON SECONDARY FLOW LOSSES IN CASCADES. N. Scholz. Braunschweig Tech. Hochschule Inst. Strömungsmech., Rep. 56/18A (AFOSR 57-39) [AD 132400], Mar. 27, 1957. 61 pp. 34 refs. Surveys of the wake in a plane behind a cascade of NACA 8410 blade sections with the top bluntly cut off the blade and without fillets at the blade foot. The solidity ratio, blade angle, and angle of inflow for the cascade are varied. The distributions of local values of the losses over the blade length and the blade distance are given, and averaged values are obtained from these by integration. Results indicate how the losses depend on the cascade geometry.

PRESSURE DISTRIBUTION MEASUREMENTS ON TWO-DIMENSIONAL CASCADES AT HIGH SUBSONIC MACH NUMBERS. I. K. H. Grewe. Braunschweig Tech. Hochschule Inst. Strömungsmech., Rep. 57/6A (AFOSR 57-289) [AD 132360], Mar. 12, 1957. 47 pp. Tests on NACA 0010 and NACA 8410 blade sections with variations in solidity ratio, blade angle, and angle of inflow. Measurements in the new DFL High Speed Cascade Wind Tunnel extend previous measurements in incompressible flow in order to determine the influence of Mach Number range on the pressure distribution of the blades. Results indicate that, up to those Mach Numbers where the velocity of sound is reached locally at the blade surface (critical Mach Number), the pressure distribution over the blade is determined by the nonviscous subsonic flow through the cascade; at higher Mach Numbers (up to the choking Mach Number), the influence of shock waves is considerable.

WYZNACZENIE CHARAKTERYSTYKI WIELOSTOPNIOWEJ SPRĘŻARKI OSIOWEJ ZŁOŻONEJ ZE STOPNI NIEJEDNORODNYCH. Bohdan Krajewski. Arch. Budowy Maszyn, No. 1, 1957, pp. 75-88. In Polish, with summaries in English and Russian. Generalization of Salzmann's method for determining the characteristic curve of a multistage axial compressor consisting of nonuniform stages. The new procedure avoids the assumption of identical compression increases and identical characteristic curves for all stages. In this way, the problem is reduced to a differential equation of the first order which can be solved by means of the Runge-Kutta method.

EFFECT OF SWEEP ON PERFORMANCE OF COMPRESSOR BLADE SECTIONS AS INDICATED BY SWEPT-BLADE ROTOR, UNSWEPT-BLADE ROTOR, AND CASCADE TESTS. William R. Godwin. US, NACA TN 4062, July, 1957. 43 pp. Measurement of the velocities of entering and exiting flow and blade-section pressure distributions at three radial stations on a 30° swept-blade rotor of 0.69 hub-tip ratio and having the same blade geometric characteristics as an NACA 65-series, unswept-blade rotor. Blade-section pressure distributions are obtained by means of a mercury-seal pressure-transfer device. Data are compared with similar data for the same blade sections obtained from a two-dimensional, porous-wall cascade tunnel and with data obtained from a previous investigation using an NACA 65-series rotor.

ÜBER DEN EINFLUSS DER GESCHWINDIGKEITSVERTEILUNG IN DER ZUSTRÖMUNG AUF DIE SEKUNDÄRSTRÖMUNG IN GERADEN SCHAUFELGITTERN. K. Gersten. Forschung Gebiete Ing., Ausg. A, No. 3, 1957, pp. 95-101. 25 refs. In German. Measurements of secondary flow losses in straight cascades for various inflow velocity distributions showing a fundamental difference in the behavior of turbine and compressor cascades. While the secondary flow in the turbine cascade remains practically independent of the inflow profile, the compressor cascade is very sensitive to changes in inflow as a result of pressure rise in the cascade. A limiting boundary-layer thickness exists, however, beyond which the secondary flow losses show no further increase with boundary-layer thickness.

ONE-DIMENSIONAL TREATMENT OF NON-UNIFORM FLOW. Appendix I - DERIVATION OF MEAN VALUE EQUATIONS. Appendix II - INTERPRETATION OF MEAN TOTAL PRESSURE. R. D. Tyler. Gt. Brit., ARC R&M 2991, 1957. 20 pp. BIS, New York, $1.08. Analysis to illustrate the errors likely to arise when the simple one-dimensional flow methods are applied to a circular-section duct in which a boundary layer exists. Graphical results are presented, for the case of a 1/7 power-law boundary-layer velocity profile, showing the ratio of the true mean values calculated with allowance for the boundary layer to quantities derived from the simple one-dimensional calculation. Conditions for one-dimensional flow of a perfect gas at a station of a duct are shown to be defined by any four independent properties, and three examples incorporating different selections of these variables are worked out in detail. General equations are presented for use in cases not covered by these examples.

ON THE APPLICATION OF A STARTING CONDITION TO THE DESIGN OF MULTI-SHOCK INTAKES. C. H. J. Johnson. Australia, ARL Mech. Eng. Note 221, May, 1957. 21 pp. Presentation of some designs for two-dimensional multishock intakes incorporating Henderson's generalized starting condition and having maximum total-pressure recovery. Consideration is first given to Oswatitsch's and then to the more general problem of determining the way in which n shocks (which, in general, are all oblique) must be arranged such that total pressure recovery across the system is a maximum.

THE INFLUENCE OF PRESSURE RATIO AND DIVERGENCE ANGLE ON THE SHOCK POSITION IN TWO DIMENSIONAL, OVER-EXPANDED, CONVERGENT-DIVERGENT NOZZLES. Appendix I, II - DESIGN DETAILS OF TEST NOZZLES. Appendix III - EFFECTS OF CONDENSATION SHOCK. P. F. Ashwood and G. W. Crosse. Gt. Brit., ARC CP 327, 1957. 27 pp. 11 refs. BIS, New York, $0.72. Tests covering a range of design pressure ratios between 3.5 and 17.0 and included divergence angles of 5° to 40°. An empirical expression is derived for calculating the limiting pressure ratio at which the nozzle just runs full. Curves are presented for finding the shock position within the nozzle. The variation with design pressure ratio of the maximum pressure ratio obtainable across the exit shock is determined and the results are compared with predictions using a semi-empirical formula derived from shock-wave/boundary-layer interaction experiments.

Stability & Control

PROBLEMS OF LONGITUDINAL STABILITY BELOW MINIMUM DRAG SPEED, AND THEORY OF STABILITY UNDER CONSTRAINT. Appendix - REMARKS ON VON KÁRMÁN AND BIOT'S CRITERION OF LONGITUDINAL STABILITY. S. Neumark. Gt. Brit., ARC R&M 2983, 1957. 37 pp. 18 refs. BIS, New York, $1.98. Derivation of a general theory of stability with restraint - i.e., when a control (elevator, throttle, etc.) is used to suppress one component of the disturbance - from development of the concept of stability of partially controlled flight. The theory may be used to provide approximate solutions of problems in which the pilot moves his control so as to keep one component of the disturbance always as small as possible. Several examples are given. Analysis of Painlevé's criterion regarding the instability of flight below minimum drag speed shows that, while this criterion is an imperfect attempt to approximate the condition for phugoid stability, it is perfectly valid for partially controlled flight.

THE AERODYNAMIC DERIVATIVES WITH RESPECT TO A RATE OF YAW FOR A DELTA WING WITH DIHEDRAL AND AT INCIDENCE AT SUPERSONIC SPEEDS. J. H. Hunter-Tod. Gt. Brit., ARC R&M 2887, 1957. 23 pp. BIS, New York, $1.26. Derivation of appropriate expressions on the basis of an unsteady-flow analysis and the assumptions of the linearized theory of flow. Only first-order terms in the rate of turn are considered. The terms dependent on the dihedral alone are continous and decrease numerically with rising Mach Number. The remaining terms are discontinous at a Mach Number at which a leading edge becomes supersonic; in particular, the rolling-moment component due to incidence changes sign, and the other derivatives may do likewise in certain circumstances.

EFFECTS OF ELEVATOR CIRCUIT STIFFNESS ON THE LOADING CONDITIONS IN LONGITUDINAL MANOEUVRES. D. R. Puttock. Gt. Brit., RAE Rep. Struc. 200, Mar., 1957. 31 pp. Theoretical investigation pertaining to a rapid pilot-induced pull-out maneuver, with particular reference to the airworthiness aspects. The solution to the problem is presented in general terms, but in view of its complexity, the salient features are discussed with reference to a numerical example. Results indicate that the loading conditions at the tail in a rapid pull-out maneuver may be significantly dependent on the degree of stiffness present in the elevator circuit, and that acceptance of the assumption that the circuit is rigid in the analysis of such maneuvers, when such a hypothesis is not justifiable, may lead to an underestimation of the critical-loading conditions.

THE EFFECTS OF VORTEX AND SHOCK-EXPANSION FIELDS ON PITCH AND YAW INSTABILITIES OF SUPERSONIC AIRPLANES. J. N. Nielsen and G. E. Kaattari. IAS Natl. Summer Meeting, Los Angeles, June 17--20, 1957, Preprint 743. 16 pp. Members, $0.50; nonmembers, $0.85. Study to describe the underlying causes of longitudinal and directional instability in supersonic aircraft, and to discuss rational design changes to alleviate the instabilities and to indicate where further research is needed. A theoretical model of the body vortex system is set up, and the vortex strengths and positions at the tail are calculated. The effects of the wing on body vortices and the tail load due to vortices are examined. The wing shock-expansion field is studied and a tail-effectiveness parameter is derived. Applications of the theory are made to both high- and low-tail aircraft. It is shown that body vortices can cause pitch-up of high-tail aircraft and that the wing shock-expansion field can either aggravate or alleviate the pitch-up. A low tail avoids the body vortices and retains good tail effectiveness to a Mach Number of 5 or more.

Wings & Airfoils

PRELIMINARY INVESTIGATION OF THE CHARACTERISTICS OF A TWO-DIMENSIONAL WING AND PROPELLER WITH THE PROPELLER PLANE OF ROTATION IN THE WING-CHORD PLANE. David H. Hickey. U. S., NACA RM A57F03, Aug. 1, 1957. 12 pp. Experimental investigation using a wing with a 4 1/2-ft. chord length. Total static lift is measured with and without the wing for a 3-ft.-diam. propeller and the effects of a ground plane on the static lift of the wing-propeller combination are measured with a 2-ft.-diam. propeller. Lift and pressure distributions are obtained at several angles of attack and free-stream air speeds from 0 to 93 ft./sec. are found with a 3-ft.-diam. wing-propeller combination.

EXAMPLES OF CALCULATION OF MINIMUM SUPERSONIC DRAG DUE TO LIFT BY SOLUTION OF TWO-DIMENSIONAL POTENTIAL PROBLEM: ELLIPTICAL-PLANFORM WINGS AND AN APPROXIMATE DELTA-PLANFORM WING. M. E. Graham. Douglas Rep. SM-22754, Mar., 1957. 15 pp. 11 refs. Application of two-dimensional potential-flow solutions to obtain minimum drag due to the lift of three-dimensional planar wings. The method of relating the two-dimensional potential problem to the three-dimensional drag-minimization problem for spatial as well as planar wing systems can be developed from combined flow-field concepts. For

the first example, the minimum drag of unyawed and yawed elliptical plan-form wings is obtained, and the drag values agree with Jones' results. For the second example, the minimum drag of a wing with a plan form very nearly that of a sonic-edge delta wing is obtained. The minimum drag value is about 11% less than that of a flat wing of the same plan form.

NORMAL-FORCE CHARACTERISTICS OF DELTA WINGS AT SUPERSONIC SPEEDS. Seymour Lampert. J. Aero. Sci., Sept., 1957, pp. 667-674, 682. Results of a series of wind-tunnel investigations presented as normal-force coefficients per radian for the Mach Number range 1.33 to 4.55. Investigation at the Jet Propulsion Laboratory, from which the data are obtained, involves the design of a family of five delta wings to cover the range of slope ratios (leading-edge slope/Mach-wave slope) from 0.15 to 4.1, and the systematic study of the lift and normal-force characteristics for these wings as a function of Reynolds Number and Mach Number. Measurements are compared with linear theory both as a function of Mach Number and slope ratio

SUPERSONIC DRAG CALCULATIONS FOR A CYLINDRICAL SHELL WING OF SEMI-CIRCULAR CROSS-SECTION COMBINED WITH A CENTRAL BODY OF REVOLUTION. B. J. Beane and B. M. Ryan. Douglas Rep. SM-22627, Oct., 1956. 33 pp. 16 refs. Theoretical determination of the wave and vortex drag for various chordwise lift distributions and for three values of a parameter describing the wing geometry. Using the wave drag obtained from the chordwise loading that gives the least drag, together with the vortex and skin-friction drags, the maximum lift-to-drag ratio for each wing geometry is computed.

ON THE INFLUENCE OF THE GEOMETRY OF SLENDER BODIES OF REVOLUTION AND DELTA WINGS ON THEIR DRAG AND PRESSURE DISTRIBUTION AT TRANSONIC SPEEDS. F. Keune and K. Oswatitsch. KTH, Stockholm, Aero. TN 42, 1956. ARDC-sponsored analysis of flow around delta and swallow-tailed wings, by comparison to flow around (equivalent) bodies of revolution. After general considerations, a geometrical system of bodies of revolution is introduced, and the suitability of this system is checked by applying it to the linear range. The drag of the forebody at Mach 1 is previously shown to be half of the linearized supersonic drag. It is shown here that the drag of the after body is practically equal to the whole supersonic drag of this part. Therefore, the closer the drag of the whole body at Mach 1 lies to the supersonic value, the greater is the contribution of the afterbody. The calculations show that the linear supersonic theory holds for all supersonic Mach numbers. The small subsonic region on the tip at the supercritical Mach Number has no appreciable influence.

AEROELASTICITY

THEORETICAL AND EXPERIMENTAL INVESTIGATIONS OF DELTA-WING VIBRATIONS. E. T. Kruszewski, E. E. Kordes, and D. J. Weidman. US, NACA TN 4015, June, 1957. 11 pp. Comparison of nodal-line patterns and frequencies of a 45° built-up delta-wing specimen obtained experimentally and compared with results calculated by two analytical methods - the idealized-structure type of method as described by Levy and a limited-deformation type of method proposed by Stein and Sanders. It is shown that when the effects of transverse shear are included into the Levy approach, the agreement between calculated and experimental frequencies is exceptionally good.

MEASUREMENTS OF SOME LOW SPEED OSCILLATORY STABILITY DERIVATIVES OF THE AGARD WING MODEL D. J. Yff. Netherlands, NLL TM F. 195, Dec. 6, 1956. 15 pp. Includes derivation of the equations of motion and description of the test technique and the apparatus. Tests are conducted in a low-speed wind tunnel at values of the reduced frequency ranging from 0.015 to 0.040, at Reynolds Numbers of 400,000-760,000. Results show no significant effect of the reduced frequency on the aerodynamic derivatives.

ON THE VIBRATION OF THIN CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE. Y. C. Fung, E. E. Sechler, and A. Kaplan. J. Aero. Sci., Sept., 1957, pp. 650-660. 12 refs. Analytical results indicate that the internal pressure has a significant effect on the natural vibrations and that, particularly for cylinders having smaller length-to-diameter ratios, the mode associated with the lowest frequency is, in general, not the simplest. Experimental data on the frequency spectra, vibration modes, and structural damping are described for a series of thin-walled cylinders subjected to internal pressures, and these data show agreement with the features predicted by Reissner's "shallow-shell" vibration theory. The effect of slight deviation of the cylinder from perfect circular symmetry is discussed.

NONLINEAR RESPONSE OF AIRCRAFT PANELS IN ACOUSTIC NOISE. E. J. Kirchman and J. E. Greenspon. J. Acoustical Soc. Am., July, 1957, pp. 854--857. Analysis of the response of thin elastic plates to sinusoidol acoustic excitation. A theoretical method for obtaining the dynamic deflection and stress in the nonlinear region is given, and comparison with test results shows rather good agreement. Applications to the design of panels to withstand acoustical fatigue are discussed.

ON THE SIMULATION OF RANDOM EXCITATIONS FOR AIRPLANE RESPONSE INVESTIGATIONS ON ANALOG COMPUTERS. Appendix A - ELECTRICAL MEASUREMENT OF POWER SPECTRUMS. Appendix B - ELECTRICAL MEASUREMENT OF PROBABILITY DISTRIBUTIONS. , Bernard Mazelsky and Harry B. Amey, Jr. J. Aero. Sci. Sept., 1957, pp. 633-649, 712. Presentation of a method of electrical simulation which permits evaluation of a wide class of aircraft dynamic problems involving random excitations (gust loads, taxi loads, buffeting, etc.). The method of synthesis is described together with the means for measuring the necessary statistical properties. In par-

ticular, the method is demonstrated for the simulation of non-Gaussian atmospheric turbulence and its application to the short-period response of an airplane over a wide range of frequencies and dampings. Nonlinear aerodynamic restoring force and damping characteristics are also considered.

FATIGUE LOADINGS IN FLIGHT-LOADS IN THE TAILPLANE OF A COMET I. Anne Burns. Gt. Brit., RAE TN Struc. 222, Mar., 1957. 19 pp. Presentation of data on the number of load cycles of various magnitudes occurring in the tailplane of a Comet IA during normal ground and flight conditions. These conditions include flight in turbulence, take-off, landing, taxiing, and ground running of the engine. The relative importance of the loads in the different conditions is illustrated by reference to the loads in a typical flight. A simple linear relationship is found to exist between tailplane load ranges and vertical gust-velocity ranges exceeded the same number of times in turbulence, except at 130 knots, 1/3 flap, when the tail load for a given gust is greater than in the general case.

FLEXURAL VIBRATIONS OF A THIN-WALLED CYLINDER OF RECTANGULAR CROSS-SECTION. E. H. Mansfield. Gt. Brit., RAE Rep. Struc. 219, Feb., 1957. 23 pp. Derivation of explicit stress-function solutions for the webs and the top and bottom surfaces for a long, cylindrical box of symmetrical rectangular cross section. The effects of shear lag and shear deflection are included inherently. The results are expressed simply in terms of an effective flexural rigidity.

AIRPLANE DESIGN

THE FAIREY DELTA 2. I - DESIGN AND CONSTRUCTION. II - SOME FEATURES OF FLIGHT TESTING ON THE FAIREY F. D. 2 LEADING UP TO THE SUCCESSFUL ATTEMPT ON THE WORLD SPEED RECORD AND SUBSEQUENT FLYING. R. L. Lickley and L. P. Twiss. RAeS J., July, 1957, pp. 439-461; Discussion, pp. 461-466. (Abridged in Shell Av. News, June, 1957, pp. 14-20.) I - Description of aerodynamic and structural design of the aircraft, summary of flutter investigations, review of general design considerations, and discussion of manufacturing problems. Emphasis is given to the drooping-nose configuration which allows for minimum wind-shield height while providing the pilot with adequate view at high angles of incidence at landing, the main undercarriage design, provisions for general servicing, engine installation, and hydraulics and power controls. II - Discussion of pre-flight and in-flight testing; of special preparations for breaking the speed record, including fuel management; of the supersonic bang and its influence on the flying program; and of supersonic flying below 30,000 ft. Details of the aircraft's intake design are appended along with pressure measurements.

Ejection Seats

DOWNWARD EJECTION FLIGHT TESTS OF A SHOCK-ABSORBING SEAT FIRING CONTROL SYSTEM. Kenneth F. Hecht and Edward G. Sperry. USAF WADC TN 55-239 [AD 118053], Feb., 1957. 42 pp. Presentation of results for 28 flight-test ejections of a downward ejection seat. Eighteen of these tests involve dummies and 10 use human subjects. Measurements of the forces encountered in the wrists when utilizing a D-ring type of firing control during downward ejection are presented. Other test results obtained from motion picture records and subjective reactions of the human subjects are reported. It is concluded that the downward ejection seat as modified for the human subject phase is a satisfactory escape device throughout the speed and altitude range tested.

AIRPORTS

BRIEF LANDING TRIALS USING THE FLUSH LIGHTING PATTERN IN THE RUNWAY AT THE ROYAL NETHERLANDS AIR FORCE STATION AT SOESTERBERG. E. N. Hooton. Gt. Brit., RAE TN Bl. 45, Mar., 1957. 20 pp. Flight tests using Varsity and Devon aircraft to examine the visual guidance provided by the approach pattern during final flare and landing. Results generally confirm ground simulator tests and indicate certain elements essential to any guidance system for landing.

ELECTRONICS

Antennas

THE ANALYSIS OF THE STRUCTURAL BEHAVIOUR OF GUYED ANTENNA MASTS UNDER WIND AND ICE LOADING. I - STRUCTURAL ANALYSIS, G. J. Schott and F. R. Thurston. II - WIND LOADS, P. J. Pocock. Canada, NRC Div. Mech. Eng. Rep. MER-1, 1956. 51 pp. Explicit description, with examples, of a method which permits the immediate use of normal computational aids to determine the distribution of bending moment, shear, axial load, and deformation in the mast, and the loads in the guy wires for a three-level, four-way guyed antenna mast erection subjected to wind load, ice accretion, and loads applied by an antenna installation at the head of the mast. Wind-tunnel test results are provided for a number of mast designs with simulated ice accretion.

FLIGHT TESTING

A VOLTAGE REFERENCE SYSTEM FOR USE WITH GALVANOMETERS IN FLIGHT TESTING. D. F. Daw. Canada, NAE LR 191, May, 1957. 18 pp. Development of a system which permits correction of flight-test data from voltage transducers, such as thermocouples, for changes in galvanometer sensitivity, resistance, or null. Changes of transducer resistance due to changes of temperature may also be compensated with this system. The system is applicable only to cases in which the galvanometer current may be calculated as the product of a function of time and a function of the deflection of the galvanometer trace from its null position, and is capable of achieving an accuracy of 0.1% of full scale.

EINE NEUE UNIVERSAL-MESSANLAGE FÜR FLUGMESSUNGEN. Rudolf Schmidt. ZFW, June, 1957, pp. 161--168. In German. Description of equipment for flight testing which permits a simul-

taneous and continuous recording of a great number of different phenomena. The recording is done by transforming the investigated phenomena into electric pulses and then into light pulses of variable duration which are recorded on photographic film in the form of periodically interrupted lines.

ICE FORMATION & PREVENTION

HELICOPTER ICING RESEARCH. J. R. Stallabrass. Canada, NAE Quart. Bul., Apr. 1-June 30, 1957. 26 pp. Investigation of the effects of icing on the handling and performance of helicopters, and development of an icing-protection system. Flight tests are carried out using a specially constructed spray array to produce a simulated icing cloud. Primary emphasis of the experiments is on the determination of icing effects on the main rotor blades. The most significant effect is shown to be an increase in drag, resulting in a drop in rotor r.p.m. which may be corrected by an increase of the throttle setting. A system of electrothermal deicing is chosen to prevent this drag increase as well as dangerous vibrations due to asymmetrical self-shedding of ice, and to eliminate the danger from large pieces of thrown ice.

INSTRUMENTS

EFFECTS OF THERMAL RELAXATION AND SPECIFIC-HEAT CHANGES ON MEASUREMENTS WITH A PNEUMATIC-PROBE PYROMETER. P. W. Kuhns. US, NACA TN 4026, July, 1957. 67 pp. 35 refs. Derivation of equations which evaluate the effects of thermal vibrational relaxation and specific-heat changes on pneumatic-probe pyrometer measurements in the region 1,000° to 3,000° K. and 0.3 < Mach Number < 2.0. Examples are given for typical probes in two combustion chambers.

THE DEVELOPMENT OF A MASS FLOW PROBE. E. R. Wolff. UTIA TN 12, Jan., 1957. 55 pp. Investigation using two specially developed circular mass-flow probes, with an entrance opening of .064 in. in diam. and .040 in. in diam., and suitable test equipment to determine all of the flow quantities in a supersonic free stream or boundary layer. Measured mass flow is used as one of the independent parameters. Results indicate that the probe is a suitable device for determining free-stream supersonic Mach Numbers and for determining boundary-layer temperature profiles in the supersonic region away from the wall of the supersonic boundary layer.

PRESSURE PROBES AT VERY LOW DENSITY. Appendix - THE IMPACT PROBE IN RAREFIED GAS FLOW. K. R. Enkenhus. UTIA Rep. 43 (TN 57-237) [AD 126534], Jan., 1957. 165 pp. Development of an orifice probe, and tests on this and conventional impact probes in the transition-flow regime and in free molecule flow. Data may be used to relate pressure readings to the free-stream Mach Number when calibrating rarefied gas streams. The probe consists of a cylinder transverse to the stream with an orifice for taking pressure readings, pierced in a piece of trifoil cemented over an opening in the side. From extensive tests with the orifice probe in the transition-flow region at Mach Numbers up to 2, an empirical formula is devised expressing orifice-probe pressure readings as a function of Mach and Knudsen Number from continuum to free molecule flow. The influence on pressure reading of such factors as outgassing, thermal transpiration, orifice geometry, etc., is investigated in detail.

MACHINE ELEMENTS

ROTATING DISKS WITH NO PLANE OF SYMMETRY. P. G. Hodge, Jr., and John Papa. J. Franklin Inst., June, 1957, pp. 505-522. Investigation of the state of stress in a rotating disc with no plane of symmetry perpendicular to the axis of rotation. Due to the variation of centroidal heights with respect to the radius, bending moments are induced in addition to the usual radial and tangential forces. The problem is defined in terms of direct stress and bending resultants in the radial and tangential directions, together with the extension and rotation of the centroidal surface. It is then reduced to the solution of two simultaneous, second-order, linear equations for two stress functions. Various methods of solution are presented and illustrated in an example.

MATHEMATICS

ON STRESS FUNCTIONS FOR ELASTOKINETICS AND THE INTEGRATION OF THE REPEATED WAVE EQUATION. E. Sternberg and R. A. Eubanks. Quart. Appl. Math., July, 1957, pp. 149-153. 11 refs. ONR-supported presentation of a completeness proof for a general solution, due to Galerkin, of the field equations in classical elasticities, and to give a relation between it and Papkovich's solution of the equilibrium equations. It is also shown that every solution of a repeated wave equation may be represented as the sum of two wave functions.

AN INTRODUCTION TO THE EQUATIONS OF MAGNETOGASDYNAMICS. Appendix - ELECTROMAGNETIC RELATIONS IN NON-RATIONALIZED GAUSSIAN SYSTEM; RATIONALIZED GIORGI SYSTEM. J. A Steketee. UTIA Rev. 9, Apr., 1957. 35 pp. 11 refs. Short discussion of Maxwell's equations pointing out some of the classical analogies with familiar hydrodynamics relations, followed by a systematic derivation of the equations of magnetohydrodynamics, assuming that the Navier-Stokes equations are known. This derivation is accomplished by combining the equations of electromagnetism with the ordinary equations of hydro- and aerodynamics.

NOTE ON WEAK CUT-POINTS IN CLANS. R. J. Koch. La. State U., Math. Div. Rep. (AFOSR TN 57-241)[AD 54304], May 15, 1957. 9 pp. 14 refs. Establishment of the equivalence of two conjectures: a) that if S is a clan which is not a group, then the unit cannot be a weak cutpoint; and b) that, under the same circumstances, the unit cannot lie in a nontrivial c-set. A clan is defined as a compact connected Hausdorff semigroup with unit. The conjectures are answered affirmatively in the case when S is either one-dimensional or homogeneous, and it is further shown that the unit of S does not

cut any subcontinuum of S in the one-dimensional case.

MECHANICS

O DOKŁADNOŚCI PEWNEJ WYKREŚLNEJ METODY WYZNACZANIA PRĘDKOŚCI I PRZYSPIESZEŃ PUNKTU. Jan Oderfeld. Arch. Budowy Maszyn, No. 1, 1957, pp. 23-32. In Polish, with summaries in English and Russian. Evaluation of the accuracy of a particular method for determining the velocity and accelerations of a point. The method consists in replacing the motion of a point on a path by the motion of a point on a polygon of chords. Velocity and acceleration in that motion are determined by geometrical addition and subtraction. The minimum sum of the systematic and the expected random error - the two errors discerned - is determined and the optimal density of points on a path is found; the density in determining velocity is shown to be different from that in determining acceleration. Results are presented in a form suitable for practical use.

MISSILES

AIDS TO INERTIAL NAVIGATION. Frederick Stevens and F. W. Lynch. IAS Natl. Summer Meeting, June 17-20, 1957, Preprint 737. 11 pp. Members, $0.35; nonmembers, $0.75. Discussion of the mechanical and natural limitations of inertial systems and of methods for "aiding" the systems to overcome these limitations. The cause of the typical 84.4-min. oscillation is analyzed, and a velocity damping method to eliminate this oscilation is described. The problem of inertial platform misalignment is discussed, and methods of stabilization through star tracking and check-point incorporation are presented.

NAVIGATION

A MONTE CARLO ANALYSIS OF THE GROUND CONTROLLED APPROACH SYSTEM. A. Blumstein. Oper. Res., June, 1957, pp. 397--408. Estimation of the distribution of airplane positions along the approach path and of the probability of successful landing when the Ground Controlled Approach (GCA) system is used. Sample flight paths of airplanes landing by GCA are generated by the Monte Carlo method and, in the analysis, the airplane is stepped through its flight path in 5-sec. increments. Sample flight paths are simulated by using random numbers to represent the stochastic variations in initial position, wind, controller decisions, and execution of turn orders.

THE POSSIBILITY OF STUDYING THE APPROACH OF AN AIRCRAFT BY MEANS OF ANALOGUE COMPUTORS. Appendix I - NUMERICAL VALUES OF THE CHARACTERISTICS OF THE BREGUET DEUX PONTS AIRCRAFT USED IN THE CALCULATIONS. T. C. Haus. (Gt. Brit., MOS TIL/P56512.) Gt. Brit., RAE Lib. Transl. 647, Mar., 1957. 53 pp. Presentation of results obtained by means of analog computers for the transverse movement of an aircraft during the period of approach, before landing on a runway of known heading. The effects of changes of various aircraft parameters are considered from the point of view of the problem under examination - the Breguet Deux Ponts aircraft. Data from two different computers, for still air conditions only, indicate that the aircraft is best brought to the correct position over the runway entrance by using a combination of aileron movement and sideslip.

THE PROBLEM OF AIRCRAFT SEPARATION OVER THE ATLANTIC. C. S. Durst. Inst. Navigation J., July, 1957, pp. 254 -263. Calculations to provide data on the position errors which aircraft are liable to make at all stages of their flights across the Atlantic, as a means of determining what constitutes a safe separation between aircraft making parallel flights and if some form of controlled paths may economically be imposed between America and Europe. Results indicate that, provided a weather central is established for the North Atlantic and forecasts are issued which all aircraft are required to use, it will be possible to plan each day optimum flight paths at about 60 or 70 miles from one another which can be used independently; on the other hand, the distance between outward and homeward tracks should be at least 120 miles in the mid-Atlantic area for aircraft flying at the same altitude.

PHYSICS

REFLECTION AND REFRACTION OF ELECTROMAGNETIC WAVES AT PLANE INTERFACES. W. E. Williams. J. Math. & Phys., Apr., 1957, pp. 26-35. USAF-supported presentation of a unified method for treating the problem at interfaces separating media of different dielectric properties. Using an extension of the method adopted by Copson for considering the diffraction of a plane harmonic electromagnetic wave by air aperture in a perfectly reflecting plane, some fairly simple results are obtained concerning the form of the solution at large distances from the source. Further extension is made to cover the case in which one surface deviates slightly from a plane.

SPECIAL ISSUES: IGY INSTRUCTION MANUAL; THE IONOSPHERE. I - IONOSPHERIC VERTICAL SOUNDINGS, J. W. Wright, R. W. Knecht, and K. Davies. II - THE MEASUREMENT OF IONOSPHERIC ABSORPTION, W. R. Piggott, W. J. G. Beynon, G. M. Brown, and C. G. Little. III - THE MEASUREMENT OF IONOSPHERIC DRIFTS, L. G. H. Huxley, B. H. Briggs, and J. S. Greenhow. IV - MISCELLANEOUS RADIO MEASUREMENTS, F. Horner, M. G. Morgan, A. C. B. Lovell, P. A. Forsyth, L. Harang, K. L. Bowles, and A. M. Peterson. IGY Ann., Vol. III, Pts. I, II, III, IV, 1957. 381 pp. 53 refs. I - Historical review and outline of the IGY program, and detailed discussion of ionospheric physics, sounding equipment, ionogram interpretation and reduction, and data quality. II - Presentation of the general theory of ionospheric absorption, theoretical and experimental study of ionospheric-absorption measurement techniques including the pulse-reflection method and the use of extra-terrestrial radio waves, discussion of ionospheric absorption and f-min, and review of some

absorption intercomparison experiments. III - Determination of ionospheric-drift velocities from three-receiver fading records, investigation of winds in the upper atmosphere by means of drifting meteor trails, summary of other drift-measuring techniques, and comparisons of drift observations and techniques. IV - Discussions of atmospheric noise measurement and of the phenomena of whistlers and dawn chorus, radio reflections from aurorae, and ionospheric forward and back scatter. Includes description of the apparatus for radio-echo meteor survey.

APPROACH TO EQUILIBRIUM IONIZATION BEHIND STRONG SHOCK WAVES IN ARGON. Harry Petscher and Stanley Byron. Annals Phys., June, 1957, pp. 270-315. 19 refs. ONR-supported theoretical and experimental investigation of the approach of high-temperature argon to the equilibrium degree of ionization. The mechanism for equilibrium can be divided into stages. The first, which accounts for about 10% of the final ionization, is apparently controlled by impurities present in the gas even after considerable care is taken to insure high purity. In the second stage, ionization by electron-atom collisions become dominant. The rate of ionization is limited by the rate of energy transfer to electrons by elastic collisions with the atoms and ions in the gas. The rate is calculated and is in good agreement with experimental measurements making use of a) the visible continuum radiation from the gas, and b) the electrostatic potentials in the gas due to the diffusion of electrons.

POWER PLANTS

Jet & Turbine

MEASUREMENTS OF THE THRUST PRODUCED BY CONVERGENT-DIVERGENT NOZZLES AT PRESSURE RATIOS UP TO 20. Appendix I, II - DERIVATION OF CORRECTION TO INDICATED THRUST. P. F. Ashwood, G. W. Crosse, and J. E. Goddard. Gt. Brit., ARC CP 326, 1957. 25 pp. BIS New York, $0.63. Tests on a series of nozzles having an included divergence angle of 20°, in order to obtain performance data at pressure ratios applicable to jet engines operating in the flight speed range M = 2 to M = 3. Detailed description is given of the test technique used which, by utilizing the ejector action of the jet from the test nozzle to reduce the exit pressure, enables a range of pressure ratios obtainable across the nozzle to be extended threefold. An empirical formula is deduced for predicting kink point - i.e., the lowest pressure ratio at which the shock system lies wholly beyond the nozzle-exit plane.

Rocket

GAS-SIDE WALL TEMPERATURES IN RIB-BACKED LIQUID-COOLED COMBUSTION CHAMBERS. J. G. Bartas. Jet Propulsion, July, 1957, pp. 784--786. Evaluation of "hot spots" on the wall of a rocket combustion chamber when a thin wall is reinforced by a thick rib. An analysis of the temperature profile along the axis of symmetry of the rib is presented in graphical form.

PROPELLANT VAPORIZATION AS A CRITERION FOR ROCKET ENGINE DESIGN; CALCULATIONS OF CHAMBER LENGTH TO VAPORIZE A SINGLE n-HEPTANE DROP. Appendix A, B - DERIVATION OF EQUATION FOR DETERMINING GAS VELOCITY. R. J. Priem. US, NACA TN 3985, July, 1957. 41 pp. 12 refs. Calculations based on droplet-evaporation theory. Results indicate that, for a given combustor length, the percentage of fuel mass vaporized can be increased by decreasing the fuel-drop size and the initial drop velocity, or by increasing chamber pressure, final gas velocity, and initial fuel temperature. These results are correlated to give a single curve of percentage of fuel evaporated as a function of the chamber length and the factors involving these parameters. Agreement is obtained with experimental data if the mass-mean-drop diams. for various injectors are assumed to be about 100 to 200 microns.

ROTATING WING AIRCRAFT

VIBRATION PROBLEMS ASSOCIATED WITH THE HELICOPTER. Appendix I - CALCULATION OF PERFORMANCE, BLADE FLAPPING AND RETREATING BLADE ANGLES. O. L. L. Fitzwilliams. Helicopter Assn. Gt. Brit. J., June, 1957, pp. 110-144; Discussion, pp. 144-155. Experimental results indicating that the helicopter is capable of smooth operation at forward speeds considerably higher than have so far been achieved. The main requirements for such smooth operation are shown to be a moderate reduction of blade-loading coefficients, the use of rotors with four or more blades, and the introduction of turbine engines. Discussion covers, in detail, mechanical and aerodynamic vibration, tests on a four-bladed Dragonfly, vibration due to blade flapping, and in-plane vibration.

FLUTTER OF A HELICOPTER ROTOR ROTATING IN ITS OWN WAKE. R. Timman and A. I. van de Vooren. J. Aero. Sci., Sept., 1957, pp. 694-702. Presentation of a theory for calculating the aerodynamic forces acting on a rotor which is rotating in still air. The usual formulas for an oscillating aircraft may be retained provided that a new circulation function is introduced. Flutter calculations show that new regions of flutter are possible and experiments with a small, two-bladed rotor model confirm this conclusion and the new theory. The additional regions of instability are explained and are shown to vanish if turbulence wires are fixed to the model. The flutter frequency is shown to be an approximate multiple of the rotor speed, indicating that an accumulation of vortices occurs in the wake.

CZĘSTOŚĆ DRGAŃ WŁASNYCH WIRUJĄCYCH ŁOPAT WIRNIKÓW NOŚNYCH ŚMIGŁOWCA. Jerzy Lipka. Arch. Budowy Maszyn, No. 4, 1956, pp. 409-435. In Polish, with summaries in English and Russian. Theoretical investigation to obtain relations expressing the angle frequencies of resonance vibrations for helicopter rotor blades having an arbitrary distribution of mass and rigidity along the span. A method is presented for finding a

specific function which satisfies all geometric, dynamic boundary, and orthogonality conditions for the blade, as well as an additional dynamic condition for blades mounted by means of joints. An example calculation is given for flexible angle frequencies of resonance vibrations, of the first and second orders, of a rotating joint blade for which linear distribution of mass and rigidity are assumed.

STRUCTURES

LINEAR PROGRAMMING AND PLASTIC LIMIT ANALYSIS OF STRUCTURES. W. S. Dorn and H. J. Greenberg. Quart. Appl. Math., July, 1957, pp. 155-167. 12 refs. ARDC-sponsored comparison of the linear programing solutions of a limit-analysis problem, and presentation of an example for each method of solution. Two codes for the solution of programing problems are written for the IBM 701 computer.

CUMULATIVE DAMAGE IN FATIGUE - A DESIGN METHOD BASED ON THE S-N CURVE. John C. Levy. RAeS J., July, 1957, pp. 485-491. Technique for presenting results of fatigue tests in which two different stress amplitudes are applied alternately. The method involves plotting log N against log (n_4/n) where N is the total cycles to failure and (n_1/n) is the fraction of cycles run at the high stress. With these coordinates, a simple geometrical construction gives a safe design methtod for the two-stress level system. The only required information is the proportion in which the two stress amplitudes are mixed. Results are checked against a wide range of experimental data from rotating-bending and push-pull tests on ferrous and nonferrous metals for any order of stressing and length of program cycle from 50 to 5 million. An equation is also developed for the three-stress level.

AN ANALYSIS OF FLEXURAL SYSTEMS UNDER ARBITRARY DISTORTION AND END LOADING. Appendix I - END LOAD FUNCTIONS FOR A SINGLE FLEXING BEAM. Appendix II - SECOND ORDER EFFECTS FOR CROSS-SPRING FLEXURAL PIVOTS. P. J. Midgley. RAeS J., July, 1957, pp. 475-484. Theoretical investigation giving particular attention to bending-moment distributions along the span of the arbitrarily distorted flexing beam, and to the effects of lengthwise strains. Cross-spring and "spider" type flexural systems are treated in detail. Curves are presented which enable the stiffness and stressing of any flexural system to be calculated for any loading conditions, subject only to the restriction that deflections are small enough to permit application of the linearized beam equations.

ON A FORMULA FOR THE TORSIONAL RIGIDITY OF THIN-SYMMETRICAL-SECTIONS. A. I. Martin. J. Math. & Phys., Apr., 1957, pp. 20-25. Analysis considering Griffith and Taylor's approximate formula as a direct consequence of St. Venant's theory of torsion - the theory indicating that the right-hand side always gives a value in excess of the true value of the torsional rigidity; however, the excess is generally negligible. Under fairly general conditions, the present investigation shows that both sides of the formula are asymptotically equal, as $h(x) \to 0$.

STAN NAPRĘŻEŃ I ODKSZTAŁCEŃ W RURZE LUB WALE WSPÓŁPRACUJĄCYCH Z PIERŚCIENIAMI LUB TARCZAMI KOŁOWYMI. Zbigniew Olesiak. Arch. Budowy Maszyn, No. 2, 1957, pp. 153-186. 14 refs. In Polish, with summaries in English and Russian. Theoretical investigation of the state of stress in a pipe or shaft aggregate with mounted rings or circular plates, in order to find the distribution of forces between the rings and a pipe of one or more layers. Application of Shapiro's solutions for thick walled pipes of infinite length leads to the development of an approximate method of solution for the function $P(\zeta)$ of interaction between the pipe and the reinforcing rings, for any concrete case. A numerical example is solved and a graph relating to mean stresses is presented. Solutions are worked out also for a number of special cases.

PHOTOELASTICITE TRIDIMENSIONNELLE ASPECTS THEORIQUES ET EXPERIMENTAUX. C. L. Gaudfernau. France, Min. de l'Air PST 330, 1957. 86 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 1,200. In French. Discussion of the fundamentals of photoelasticity and of the three systems used to study three-dimensional stresses. These systems are: (a) the frozen-stress system in which the model, heated, stressed, and cooled under load, is cut into thin sections for examination by polarized light; (b) Favre-Mesnager technique incorporating a section of photoelastic material in the model at the zone under study; and (c) use of a three-dimensional transparent model and examination of the light diffused from centers of stress along preselected axes. Includes discussion of a practical application as an example and experimental determination of stresses in a plane beam under torsion.

Beams & Columns

THE DESIGN OF THE WEBPLATES OF LIGHT ALLOY PLATE GIRDERS. K. C. Rockey. (Internatl. Assoc. for Bridge and Struc. Eng., 5th Internatl. Cong., Lisbon, 1956.) ADA Res. Rep. 32, June, 1956. 15 pp. 17 refs. Summary of test results on webplates subjected to pure bending, pure shear, and combinations of shear and bending. New formulas are recommended for design of intermediate vertical stiffeners and the economical design of light-alloy webplates. The new formulas propose that webplates in certain instances should be designed to operate in the postbuckled stage.

Connections

INTERFACE THERMAL CONDUCTANCE OF TWENTY-SEVEN RIVETED AIRCRAFT JOINTS. Martin E. Barzelay and George F. Holloway. US, NACA TN 3991, July, 1957. 23 pp. Test results on aluminum joints consisting of a T-stringer riveted to a skin surface under simulated aerodynamic heating with no external loading applied. Rivet size and pitch are found to influence the conductance but the rivet materials tested have no observable effect. It is also found that the thickness of the skin has an

influence on the value of the conductance. The dimensions of the T-stringer are found to have no consistent influence.

THE APPLICATION OF LIMIT ANALYSIS TO THE DETERMINATION OF THE STRENGTH OF BUTT JOINTS. R. T. Shield. Quart. Appl. Math., July, 1957, pp. 139-147. 11 refs. Analysis to determine the upper and lower bounds for the tensile strength of a butt joint consisting of a thin layer of adhesive joining the parallel flats of two rigid adherents. The adhesive is assumed to be an elastic, perfectly plastic material which yields when the maximum shear stress reaches a critical value. The methods used apply to any joint with a convex area of cross-section. Particular application is made to joints whose cross-sections are circular, rectangular, or a polygon circumscribed about a circle.

Cylinders & Shells

BOUNDS ON INFLUENCE COEFFICIENTS FOR CIRCULAR CYLINDRICAL SHELLS. Eric Reissner and M. B. Sledd. J. Math & Phys., Apr., 1957, pp. 1-19. Analysis involving rotationally symmetric deformations of a thin, elastic cylindrical shell of variable wall thickness and of finite or semi-infinite axial length. One of the two edges of the shell is a free edge; the other is acted upon by a uniformly distributed bending moment and radial force. The upper and lower bounds for the values of the direct and inverse influence coefficients are determined by applying the minimum principles for displacements and for stresses of the theory of elasticity. Detailed consideration is given to the case of a semi-infinite, circular, cylindrical shell with exponentially varying wall thickness.

ASYMPTOTIC SOLUTIONS OF A CLASS OF ELASTIC SHELLS OF REVOLUTION WITH VARIABLE THICKNESS. C. Nevin DeSilva and P. M. Naghdi. Quart. Appl. Math., July, 1957, pp. 169-182. 11 refs. OOR-supported solutions to equations for shells of variable thickness. First, the implications of the thickness variation which lead to the complex differential equation are studied in detail in a form amendable to treatment by Langer's method of asymptatic integration, and then the asymptotic solutions are given which are valid at turning points of the differential equation.

UTRATA STATECZNOŚCI POWŁOKI CYLINDRYCZNEJ PODDANEJ JEDNOCZEŚNIE SKRĘCANIU I ŚCISKANIU. Stanisław Wiśniewski. Arch. Budowy Maszyn, No. 4, 1956, pp. 437-469. In Polish, with summaries in English and Russian. Analysis of the stability loss in a cylindrical shell subjected simultaneously to torsion and compression. A general solution defining the displacements of the shell after loss of stability is derived from the known equations of neutral balance for a shell element, deduced on the basis of the classical theory of shells, and by introducing the differential operator and the displacement function. The general conditions for stability are determined for a cylindrical shell with freely supported edges, and consideration is given to the case of a cylinder whose length is at least three times as great as its diameter.

Elasticity & Plasticity

FLEXURAL WAVES IN ELASTIC BEAMS OF CIRCULAR CROSS SECTION. H. N. Abramson. ASA J., Jan., 1957, pp. 42-46. 21 refs. Application of the exact equations of elasticity to investigate the flexural vibrations of a solid circular cylinder. It is shown that the phase-velocity-wavelength relation has an infinity of branches, and the three lowest of these are calculated and used to study the rate of energy transmission in terms of group velocity.

WAVE PROPAGATION IN ELASTIC PLATES: LOW AND HIGH MODE DISPERSION. Ivan Tolstoy and Eugene Usdin. ASA J., Jan., 1957, pp. 37-42. 25 refs. Analysis for an infinite elastic plate of Poisson's ratio 0.25. The properties of the lower modes and the phenomena of opposite phase and group velocities are considered; the behavior of high modes, their definition by means of Mindlin's lattices, and certain general analogies are described; and some general conclusions pertaining to layered media are discussed.

THE CENTRE OF SHEAR FOR A MATERIAL HAVING A NON-LINEAR STRESS-STRAIN CURVE. W. Johnson and P. B. Mellor. Appl. Sci. Res., Sect. A, No. 5-6, 1957, pp. 467-477. Theoretical investigation of the effect on the position of the center of shear for a semicircular and a channel section when open-section, thin-walled cantilevers are loaded in simple bending and such that parts of the section become plastic. It is assumed that the stress-strain relation in the plastic range is sufficiently well summarized by a simple power law. Explicit expressions are derived for the semicircular section and a particularly simple one is found for the channel section. The present solution is compared with that of Handelman, and numerical examples are presented.

Plates

AN EXACT SOLUTION FOR FREE RECTANGULAR PLATES LATERALLY LOADED. Luigi Broglio. Roma U. Sch. Aero. Eng. Inst. Aero. Construç. SIARgraph 8 (AFEOARDC TN 2; AFOSR TN 57-288) [AD 132359], Aug., 1956. 116 pp. Consideration of the general problem of the rectangular plate of constant thickness, under any load distribution. A solution method is presented in which the loads are reduced to conditions of symmetric or antisymmetric edge loads. Six typical problems are worked out and numerical examples are given to illustrate the method.

DAS BEULPROBLEM DER ORTHOTROPEN PLATTE MIT HOHLSTEIFEN. Alf Pflüger. ZFW, June, 1957, pp. 178--181. In German. Analysis of buckling of rectangular orthotropic plates under compression with the anisotropy generated by a panel of constant thickness carrying a series of stiffeners of closed hollow section.

SHEAR BUCKLING OF SIMPLY SUPPORTED RECTANGULAR PLATES TAPERED IN THICKNESS. Bertram Klein. J. Franklin Inst., June, 1957, pp. 537-541. Presentation of design curves for determining the elastic buckling loads of a class of simply supported rectangular plates linearly tapered in thickness in one direction and loaded in pure shear. The problem is solved by a simple numerical method involving a very small matrix.

SHEAR BUCKLING OF SIMPLY SUPPORTED PLATES TAPERED IN PLANFORM. Bertram Klein. J. Franklin Inst., July, 1957, pp. 43--48. Derivation of a simple, approximating set of equations for calculating the shear buckling loads of isosceles trapezoidal plates. A numerical example is worked for a typical plate. It is shown that the shear-buckling loads of other tapered plates may be calculated similarly, but that, for plates with relatively large values of plate-taper semi-angle, a nodal line may occur approximately in the direction of the x (rectangular coordinate) axis.

ON THE BUCKLING OF AN ELLIPTIC PLATE WITH CLAMPED EDGE. II. Yoshio Shibaoka. J. Phys. Soc. Japan, May, 1957, pp. 529-532. Analysis for the case in which the periphery of the plate is subject to a uniform normal pressure in the plane of the plate. Numerical calculations are performed and the relationship between the critical buckling load and the eccentricity of the elliptic plate is shown graphically.

Thermal Stress

A VARIATIONAL THEOREM FOR CREEP WITH APPLICATIONS TO PLATES AND COLUMNS. J. L. Sanders, Jr., H. G. McComb, Jr., and F. R. Schlechte. US, NACA TN 4003, May, 1957. 23 pp. 12 refs. Presentation of a theorem along with solutions to problems of creep bending and creep collapse for plates, columns, beams, and shells. The solutions are obtained by means of the calculus of variations in conjunction with the stated theorem.

STAN NAPRĘŻENIA W TARCZACH WYWOŁANY DZIAŁANIEM ŹRÓDEŁ CIEPŁA. Witold Nowacki. Arch. Budowy Maszyn, No. 2, 1957, pp. 121-152. In Polish, with summaries in English and Russian. Theoretical determination of the components of the thermal stress condition in an infinitely long strip of plate with one heat source, an infinitely long strip of plate with identical heat sources evenly spaced, a semi-infinite strip of plate with one heat source, and a rectangular plate with one heat source.

Wings

THE DEFORMATION OF A LONG SWEPT WING WITH CHORDWISE VARIATION OF THE THICKNESS. E. C. Capey. Gt. Brit., RAE TN Struc. 221, Mar., 1957. 33 pp. Calculation, by means of the extensional theory for thin flat plates, of the stress distribution in a long, swept-back, solid, thin wing under a bending or torsional moment. Solutions are given for all sweep-back angles for strips whose cross-sections are rectangular, diamond-shaped, parabolic, and double-wedge shaped.

THERMOELASTIC DISTORTION AND WING STRUCTURAL DESIGN. John H. Meyer. (ARDC-sponsored Symp. on High-Speed Aerodynamics and Struc., U. Fla., Jan. 21--24, 1957, Paper.) Aero. Eng. Rev., Sept., 1957, pp. 46-53. Revised. Review of laboratory and flight-test programs involving structures at elevated temperatures. Various methods of detail structural design are examined to show their limitations and possibilities. Considered are design problems posed by operating conditions, cover-plate design, wing cover-plate weights, skin panels, spar construction, leading- and trailing-edge structure, and structural optimization.

EIN NEUES VERFAHREN ZUM MESSEN DER PRANDTLZAHL UND DER WÄRMELEITZAHL VON GASEN. E. R. G. Eckert and T. F. Irvine. Forschung Gebiete Ing., Ausg. A, No. 3, 1957, pp. 91--94. 11 refs. In German. Development of a new method for measuring Prandtl Number and heat conductivities in gases, based on the relation between this number and the dimensionless temperature parameter. This parameter describes the temperature assumed by an unheated flat plate under the influence of internal heat dissipation in a fluid stream of high velocity with a laminar boundary layer along the surface of the plate. Prandtl Numbers of air measured at atmospheric pressure and at temperatures between 15° and 180° C. by means of a specially designed test apparatus show the degree of accuracy which can be expected.

THERMODYNAMICS

BILANS POTENCJONALNY PROCESÓW CHEMICZNYCH. Jan Szargut. Arch. Budowy Maszyn, No. 1, 1957, pp. 89-117. In Polish, with summaries in English and Russian. Principles for calculating the energetic potential of an agent participating in a chemical process. It is shown that in making the potential balance of chemical processes - just as in balancing them energetically - it is possible to establish, independently of one another, only as many conditions of reference as there are elements participating in the process. A formula is derived for the energetic potential of a jet of the working fluid cutting through a fixed diathermic envelope. Detailed consideration is given to the problem of calculating the energetic potential in the case of balancing processes in which the elements N, O, C, H, Ar, Ne, and He take part. The potential efficiency of chemical processes is defined and an example is given of the potential balance of a process in which the combustion phenomenon appears.

ZAGADNIENIE PRZEPŁYWU CIECZY W PRZEWODACH ROZGAŁĘZIONYCH Z UWZGLĘDNIENIEM WYMIANY CIEPŁA. Jan Rościszewski. Arch. Budowy Maszyn, No. 4, 1956, pp. 333-363. In Polish, with summaries in English and Russian. Analysis of the problem of flow in ramified tubes, taking into account the effects of heat exchange. Starting from the Navier-Stokes equations, a formula is derived for the change of pressure on a segment of a single vertical tube under the assumption

of constant (mean) value of the viscosity coefficients of the fluid and of heat conduction. A method is presented for calculating the rate-of-flow distribution in the ramifications for flow in tubes with parallel ramifications in the form of heaters. A method is also developed for determining the number of heater ribs. Includes investigation of a substitute solution.

VIBRATIONAL RELAXATION PHENOMENA IN A SHOCK TUNNEL. W. J. Lick and T. Y. Li. Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE 5704 (AFOSR TN 57-346) [AD 132419], June, 1957. 27 pp. Theoretical investigation of the effect of the vibrational heat-capacity lag on the steady flow, in a shock tunnel, of an imperfect gas, i.e., one in which the specific heats are a function of temperature and time. The energy constant and the adjustment to equilibrium of the various degrees of freedom are discussed and a numerical example is given to compare the properties of an imperfect gas under the assumptions of equilibrium flow (zero relaxation times), relaxed flow (finite relaxation times), and frozen flow (infinite relaxation times) for a particular shock tunnel.

EXPLICIT EQUATIONS FOR THE CALCULATION, OF EQUILIBRIUM GAS COMPOSITIONS AT HIGH TEMPERATURES: THE HYDROGEN+CARBON+OXYGEN AND THE HYDROGEN+CARBON+OXYGEN+NITROGEN SYSTEMS WITHOUT SOLID CARBON FORMATION. F. J. Weinberg. Royal Soc. (London) Proc. Ser.A, July 23, 1957, pp. 132-140. Description of a method which overcomes the difficulties arising in calculations of flame temperatures and thermodynamic functions for gases at high temperatures, which involve the computation of gas compositions under the effects of several dissociation equilibria. It is shown that, for solution by successive approximations, explicit equations can be applied to the assumed values in terms of those assumed values. Such equations need be derived only once for each set of basic constituents and this is done for two of the most common practical cases - the C+H+O and the C+H+O+N systems without carbon deposition.

Combustion

A THEORY OF FLAME PROPAGATION LIMITS DUE TO HEAT LOSS. E. Mayer. ARDE Assoc. TN 4555-6 (AFOSR TN 57-296) [AD 132367], June, 1957. 34 pp. 21 refs. Deduction of flame-propagation limit criteria for the special cases of convective heat loss applicable to flame quenching in a circular tube and radiative heat loss applicable to free flames near the composition limit. Illustrative numerical applications are made to hydrocarbon/air data. The theoretical results for both quenching and composition limits are in satisfactory agreement with the observed data.

PRELIMINARY INVESTIGATION OF PROPANE COMBUSTION IN A 3-INCH-DIAMETER DUCT AT INLET-AIR TEMPERATURES OF 1400° TO 1600° F. Erwin A. Lezberg. U.S., NACA TN 4028, July, 1957. 19 pp. Experiments to determine ignition delays and combustion efficiencies for propane injected into a heated airstream. Spontaneous-ignition delays of 7 to 49 milliseconds are shown to occur with a single-tube injector at temperatures between 1,395° and 1,585° F. These results follow the Arrhenius relation with an apparent activation energy of 43 kilocalories per mole. Flames stabilized at the fuel injector burn to high efficiencies in lengths of 6 in. or more and are insensitive to changes in air temperature, pressure, or fuel-air ratio. Flames stabilized downstream of the injector by spontaneous ignition burn only to 70% - 80% completion at a length of 18 in.

PROPAGATION OF A TURBULENT GAS JET IN A MEDIUM WITH A DIFFERENT DENSITY. L. A. Vulis and N. N. Terekhina. Soviet Physics - Tech. Physics, No. 6, 1957, pp. 1,249-1,263. 12 refs. Translation. Derivation of an approximate solution to the problem for the basic part of the axially symmetric jet. Results of experiments in a wide range of variables of the density of the gas in the stream to that in the surrounding medium are presented to verify the similarity of the momentum current density field. It is proved that a unique regularity exists in the turbulent mixing of gases of different densities, independent of the reason for this difference (whether due to a temperature difference or a difference in the molecular weights).

Heat Transfer

THE INFLUENCE OF FREE-STREAM TURBULENCE ON HEAT TRANSFER BY CONVECTION FROM AN ISOLATED REGION OF A PLANE SURFACE IN PARALLEL AIR FLOW. Appendix I - CONFIGURATION FACTOR FOR LAMINAR FLOW. Appendix II - CONFIGURATION FACTOR FOR TURBULENT FLOW. Appendix III, IV - PROMOTION OF TURBULENCE BY MEANS OF GRIDS. A. Edwards and B. N. Furber. IME Proc., No. 28, 1956, pp. 941 - 954. 18 refs. Experiments using an isolated arrangement in order to cover a suitable Reynolds Number range and to avoid the complication of laminar, transition, and turbulent boundary layers existing simultaneously over the transferring region. Includes investigation of the influence of a square nose on the plate, with no turbulence grid fitted in the tunnel. Results are presented in graphical form for Nusselt Number vs. Reynolds Number. The mean heat-transfer coefficient is corrected for conduction (edge) and radiation losses.

HEAT TRANSFER TO FLUIDS IN THE REGION OF THE CRITICAL TEMPERATURE. Appendix--- ANALYSIS OF FLOW OF HEAT IN ELECTRICALLY HEATED TUBE. Walter B. Powell. Jet Propulsion, July, 1957, pp. 776--783. 13 refs. Army-sponsored experimental investigation of heat transfer by forced convection in the region of the critical temperature, using oxygen at supercritical and subcritical pressures. Near the critical temperature there exists a minimum in the heat-transfer coefficient which is appreciably lower than the value

at lower or higher temperatures. This phenomenon will limit the use of this liquified gas as a heat-transfer fluid.

TRANSIENT HEAT CONDUCTION IN SOLID BODIES BOUNDED BY ORTHOGONAL COORDINATE SURFACES. I - THREE-DIMENSIONAL TEMPERATURE FIELD. M. G. Kogan. Soviet Physics - Tech. Physics, No. 6, 1957, pp. 1,155-1,164. 14 refs. Translation. Investigation of the three-dimensional temperature fields in uniform, isotropic bodies (with constant physical parameters), caused by nonstationary volume and surface distributions of heat sources with nonuniform boundary conditions of the first, second, or third kind. Consideration is given to hexahedrons formed by the intersection of three pairs of orthogonal coordinate surfaces, as well as degenerate Lame hexahedrons (whose faces flow into each other, contract to a point or line, or are located at infinity).

WATER-BORNE AIRCRAFT

MARTIN MODEL 270 WATER LOADS INVESTIGATION. I - STRUCTURAL AND IMPACT LOADS CONSIDERING AIRPLANE FLEXIBILITY, Robert Schwab and E. Widmayer, Jr. II - HULL BOTTOM PRESSURES AND IMPACT LOADS, D. A. King and R. C. Adams. Martin Rep. ER 7515; ER 7516, Nov., 1955. 98, 140 pp. 27 refs. Development of a theory for calculating structural loads due to water-landing impact; calculation of these loads over a wide range of landing conditions; measurements of structural loads (accelerations and strains) and of hull-bottom pressures resulting from landings of the M-270 airplane; and comparison and correlation of experimental and theoretical loads due to impact landings on smooth seas.

WIND TUNNELS & RESEARCH FACILITIES

THE SHOCK TUNNEL AND ITS APPLICATIONS TO HYPERSONIC FLIGHT. A. Hertzberg. Cornell Aero. Lab. Rep. AD-1052-A-5 (AFOSR TN 57-268) [AD 126567], June, 1957. 44 pp. 44 refs. Discussion covering high-temperature effects in hypersonic flow, the modified shock tube, problems of hypersonic shock-tunnel instrumentation, shock-wave attenuation, the tailored-interface shock tunnel, techniques for generating strong shock waves, and hypersonic-flow shock-tunnel programs. In particular, a technique is described for accurately measuring heat transfer within the short testing times available in shock tunnels, and results are presented for preliminary experiments carried out to explore the effects of shock attenuation on the operation of shock tunnels. A new technique for generating the strong shock waves required is also described, and the experimental program under way at Cornell Aeronautical Laboratory is reviewed.

SINGLE CYLINDER ENGINE TEST INSTALLATION FOR SIMULATING FLIGHT OPERATIONS. O. W. Stewart. Ky. U., Coll. Eng., Eng. Exp. Sta. Bul. 4, June, 1957. 35 pp. Description of equipment, operational procedure, and basic test data in conjunction with the establishment of an R-2800 single-cylinder test facility, utilizing a C. U. E. engine, at the Wenner-Gren Aeronautical Research Laboratory, University of Kentucky. The test facility is capable of simulating flight conditions of a full-scale reciprocating aircraft engine. Test procedures and operating techniques have been developed and checked out by making two 100-hr. runs for establishing reproducibility of results, these runs being performed with a standard aviation fuel grade 115/145.

LA RENOVATION DE LA SOUFFLERIE S3 DU SERVICE TECHNIQUE AERONAUTIQUE. Robert Lecardonnel and M. Giqueaux. Appendix - CALCUL AERODYNAMIQUE D'UNE HELICE VENTILATEUR. M. Gruzon. France, Min. de l'Air BST 119, 1957. 110 pp. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 1,300. In French. The renovation of the S3 wind tunnel of Service Technique Aéronautique (STA) is described in detail covering: improvement of the air flow and of the effective working velocity; installation of 2,000-h. p. power unit, the filter chamber, and the regenerator, and addition of the experimental throat; increase of the tunnel work coefficient; and description of experimental and final materials and designs.

INSTRUMENTATION TO MEASURE GAS-PHASE COMPOSITION OF HIGH VELOCITY, TWO-PHASE, TWO-COMPONENT FLOWS. Appendix - APPROXIMATE EVALUATION OF ERRORS IN DROPLET "SHEDDING" PROCESS OF VAPOR-SAMPLING PROBE. K. R. Wadleigh and R. A. Oman. (ARS 11th Annual Meeting, New York, Nov. 26--30, 1956.) Jet Propulsion, July, 1957, pp. 769-775, 783. 11 refs. Discussion of the current state of development of a probe designed to measure the local water vapor-air mass-flow ratio (specific humidity). Particular emphasis is placed on the flow of liquid water droplets suspended in air-water vapor mixtures, with water-air mass ratios up to 0.3 and flow velocities from 350 to 600 ft./sec. The mechanism of operation and the development of special probes to remove "true point sample" of the gas are described.

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Russian. Description of a static transfer device for a pulse-frequency telemetering system.

Wave Propagation

Propagation Characteristics of Low-Loss Tubular Waveguides. H. E. M. Barlow and H. G. Effemey. (*IEE Paper 2326 R.*) *Proc. IEE, Part B*, May, 1957, pp. 254–260. Experimental and theoretical investigation to establish the practicability—from the standpoint of achieving low losses—of a number of different waveguide runs erected with tolerances likely to be acceptable in an engineering installation.

Space Charge Waves Along Magnetically Focused Electron Beams. Johannes Labus. *Proc. IRE*, June, 1957, pp. 854–861. 12 refs. Theoretical and experimental determination, by boundary conditions, of the propagation of perturbations along electron beams of finite diameter. A cylindrical, uncompensated beam (void of ions) confined by an arbitrary coaxial magnetic field is considered and two different procedures are compared.

Equipment

Environmental Simulation: A Tool for the Contemporary Engineer. H. John Cail. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 734.* 11 pp. Members, $0.35; nonmembers, $0.75. Discussion of the history of environmental simulation, and future environmental test requirements and simulation equipment. The types of tests commonly performed and general classes of environmental simulation equipment in current use are described.

Electric

Environmental Testing of Avionic Equipment. R. H. Douglass, Jr. *IAS Natl. Summer Meeting, Los Angeles, June 17–20, 1957, Preprint 735.* 11 pp. Members, $0.35; nonmembers, $0.75. Description of an environmental laboratory; its organization, equipment, and the type of tests performed.

Les Matériaux Electrotechniques Nouveaux. M. J. Henry Baudot. *Tech. et Sci. Aéronautiques*, No. 2, 1957, pp. 93–96. In French. Theoretical considerations of the possibilities of electric motors in aeronautical application.

Concerning the Chemical Composition of the Nickel Oxide Electrode in the Jungner-Edison Accumulator. Julian Zedner. (*Z. für Electrochemie*, No. 11, 1905, pp. 809–813.) *Gt. Brit., RAE Lib. Transl. 642*, Mar., 1957. 8 pp.

Concerning the Chemical and Physical Behaviour of the Nickel Oxide Electrode in the Jungner-Edison Accumulator. Julian Zedner. (*Z. für Elektrochemie*, No. 12, 1906, pp. 463–473.) *Gt. Brit., RAE Lib Transl. 643*, Mar., 1957. 17 pp. 20 refs.

L'Eclairage Extérieur à Bord des Aéronefs. J. Benquey. *Tech. et Sci. Aéronautiques*, No. 1, 1957, pp. 31–43. 18 refs. In French. Discussion of exterior lighting systems in aircraft, with details of their location, operation, and characteristics.

Hydraulic & Pneumatic

Physical and Chemical Laboratory Evaluation of Experimental Silicate Base High Temperature Hydraulic Fluids. IV—MLO 8200. H. M. Schiefer and R. J. Benzing. *USAF WADC TR 55–89, Pt. IV [AD 118123]*, Mar., 1957. 17 pp. Test results for viscosity-temperature relationship, spontaneous-ignition temperature, oxidation and corrosion, thermal and hydrolytic stability, foaming, lubricity, and rubber compatibility.

Some Effects of Valve Friction and Stick Friction on Control Quality in a Helicopter with Hydraulic-Power Control Systems. B. Porter Brown and John P. Reeder. *U.S., NACA TN 4004*, May, 1957. 8 pp. Test results which show that, when valve friction is equivalent to about 1.25 lbs. of force at the stick, precision flying is difficult and more work is required of the pilot. Control quality is improved by adding an amount of stick friction that is equal to the valve friction.

Hydraulic Servo Control Valves. II—An Investigation of a Number of Representative Electro-Hydraulic Servo Valves. Appendix I—**The Formulation of Dynamic Test Procedures.** Appendix II—**Servo Valve Test Procedures.** Appendix III—**Description of Laboratory Equipment** Appendix IV—**Static and Dynamic Test Results Presented in Graphical Form.** Appendix V—**Sample Calculation of the Valve Constants and Load Natural Frequencies.** Bernard Johnson and Lee Schmid. *USAF WADC TR 55–29, Pt. 2 [AD 97222]*, Aug., 1956. 220 pp.

Flight Operating Problems

Automatic Flare-Out for Landing. David Markusen, Robert McLane, and Orville Pomeroy. *USAF WADC TR 55-506 (OTS PB 121383, $3.75)*, Mar., 1956. 133 pp. 15 refs. Study and flight tests of a flare-out system which will take over pitch control of the aircraft from the glide-slope equipment at an altitude of about 100 ft. Requirements for flare-out of the DC-3 and F-94c are investigated first. As a result of the study a nonlinear computer which varies the coefficient in the rate term of the flare-out equation is constructed for flight tests.

Flight Testing

Real-Time Analysis of Flight-Test Data. Ralph Tripp and R. L. McConaughy. *ISA J.*, June, 1957, pp. 226–229. Description of a mobile station equipped with an analog computer that analyzes data fast enough to permit the ground crew to advise the pilot of the success and safety of his test maneuvers.

The Test Pilot and the Flight Test Engineer. O. B. Philp and K. D. J. Owen. *CAI Annual Gen. Meeting, Ottawa, May 27, 28, 1957, Preprint 7/3.* 15 pp. Members, $0.50; nonmembers, $1.00. Discussion of the training and duties of flight-test personnel.

Fuels & Lubricants

Gasoline to Kerosene to "Zip"—with Energy Calling the Signals. *Jet Propulsion*, June, 1957, pp. 682, 689, 690. Discussion of current military use of a variety of propellant fuels.

Development of Fluoro-Silicone Elastomers. Paul Tarrant and George W. Dyckes. *USAF WADC TR 55–220, Pt. 2*, May, 1956. 18 pp. Theoretical and experimental study of the effect of various initiators or catalysts on the addition reaction involving a single olefin-silane system.

Heat Capacities of Synthetic Engine Oils and Lubricants. Hyman Marcus. *USAF WADC TR 57-38 [AD 118225]*, Apr., 1957. 10 pp. Measurements using a modified adiabatic-type calorimeter. Includes determination of heat-capacity variation as a function of temperature for eleven synthetic fluids, and derivation of appropriate expressions from a least-squares statistical analysis of the time-temperature data.

Alaskan Test Site Oil Exposure Program. Robert J. Benzing. *USAF WADC TR 56-1 [AD 110702]*, Jan., 1957. 53 pp. Qualitative daily visual observations and monthly pour-point data on ten mineral oils and four diester oils, accumulated over a two-year period, to determine the effect of prolonged outdoor unheated shed storage on their pour points.

Micro Lubricant Test Methods. V—High Temperature Viscosity. John B. Christian. *USAF WADC TR 55–449, Pt. V [AD 118048]*, Feb., 1957. 6 pp. Introduction of a small-scale method for determining viscosity at temperatures ranging from 550° to 700° F. Method makes use of the small-scale replica of the modified Ostwald Viscometer employing 1.5 milliliters of sample.

Micro Lubricant Test Methods. IV—Evaporation Loss of Lubricating Greases and Oils, Viscosity of Lubricants at −65° F, and Foaming Characteristics of Crankcase and Aircraft Engine Lubricating Oils. John B. Christian. *USAF WADC TR 55–449, Pt. IV [AD 110587]*, Nov., 1956. 12 pp.

Development of Schematic Analytical Procedures for Synthetic Lubricants and Their Additives. Francis S. Bonomo. *USAF WADC TR 54–464, Pt. III [AD 118215]*, Apr., 1957. 54 pp. Presentation and discussion of methods for separating, identifying, and determining certain components—including such base oils as dibasic acid and silicate esters, disiloxanes, silicone oils, and selenide and phenol-type antioxidants—of synthetic greases and lubricants.

High Temperature Antioxidants for Synthetic Base Oils. VII—Evaluation of Antioxidants in Synthetic Fluids. Appendix A—**Tables of Oxidation Data.** Appendix B—**Code Numbers, Formulas and Sources of Supply of Additives and Fluids.** James W. Cole, Jr. *USAF WADC TR 53–293, Pt. 7 [AD 110728]*, Jan., 1957. 76 pp. 16 refs.

How Abrasive Contaminants Affect Aircraft-Engine Performance. F. E. Tobin, G. R. Furman, and K. H. Strauss. (*SAE Annual Meeting, Detroit, Jan. 14–18, 1957, Preprint 38.*) *SAE J.*, June, 1957, pp. 89–91.

Trends in Lubrication. R. O. Campbell and S. C. M. Ambler. *CAI Annual Gen. Meeting, Ottawa, May 27, 28, 1957, Pre*

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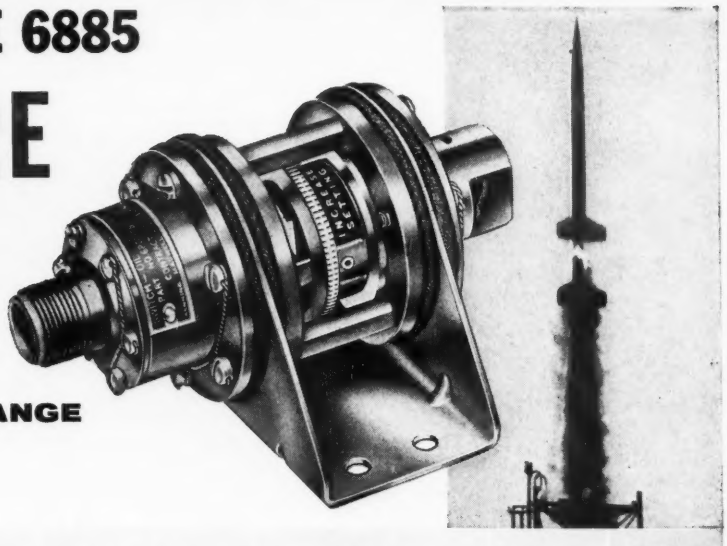

PRESSURE ADJUSTMENT RANGE	15 to 25 psia	0.25 to 4 psi	2 - 10 psi	10 - 50 psi	50 - 150 psi	150 - 500 psi	500 - 800 psi	600 to 3,000 psi	DUAL VERSION
ACCURACY OF SETTING (Under all test conditions)	±1 psi	±0.3 psi at 2.5 psi setting	±0.5 psi at 5 psi setting	±4% at 50 psi setting	±3% at 100 psi setting	±4% at 500 psi setting	±4% at 800 psi setting	±60 psi at 3000 psi setting	According to selected ranges
PROOF PRESSURE (Without setpoint drift)	500 psi	100 psi	750 or 4,500 psi (as required)	750 or 4,500 psi (as required)	750 or 4,500 psi (as required)	750 or 4,500 psi (as required)	4,500 psi	4,500 psi	250 psi
BURST PRESSURE	750 psi	450 psi	1,000 or 7,500 psi (as required)					7,500 psi	450 psi
TEMPERATURE RANGE	−75° F. to +250° F.								
VIBRATION	Up to 2,000 cps at 40 g. Exceeds MIL-E-5272A Procedure I								
OVERALL DIMENSIONS	Switch Proper—2" Diameter; Length 4⅜". Mounting Bracket to Suit Application								3½" wide 4⅜" long
WEIGHT	9 Ounces							10.5 Ounces	16 Ounces
ELECTRICAL RATING	30 Volts, 2.5 Amperes Inductive Load at 50,000 Feet								

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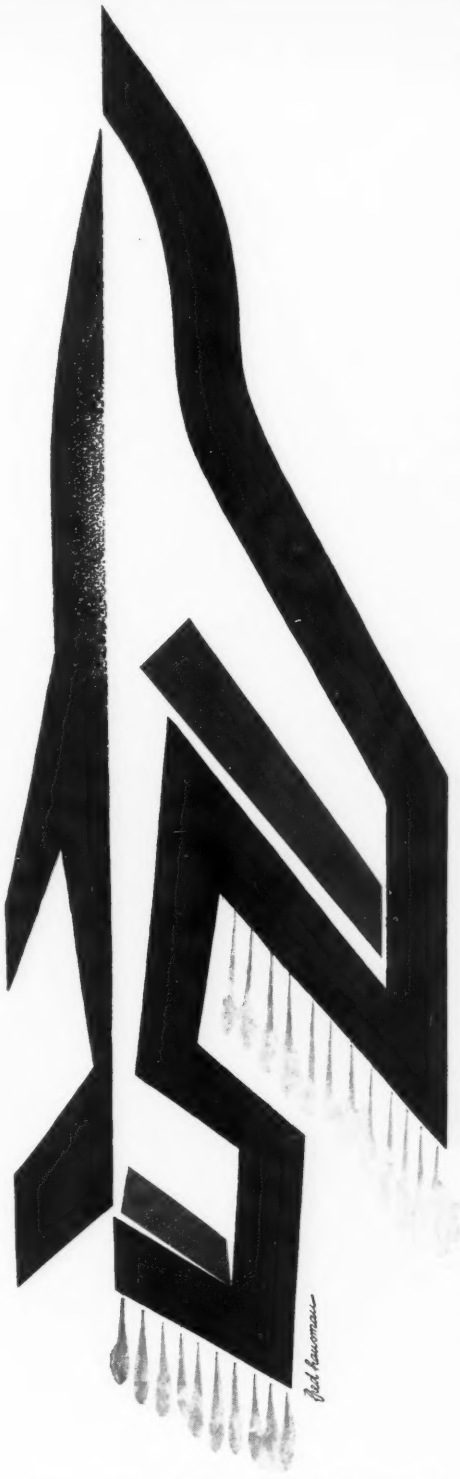

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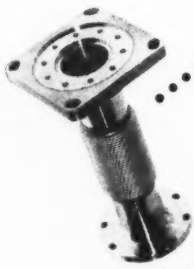

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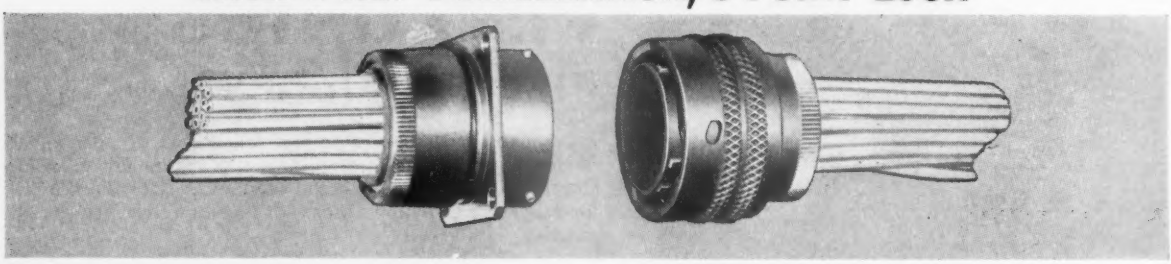

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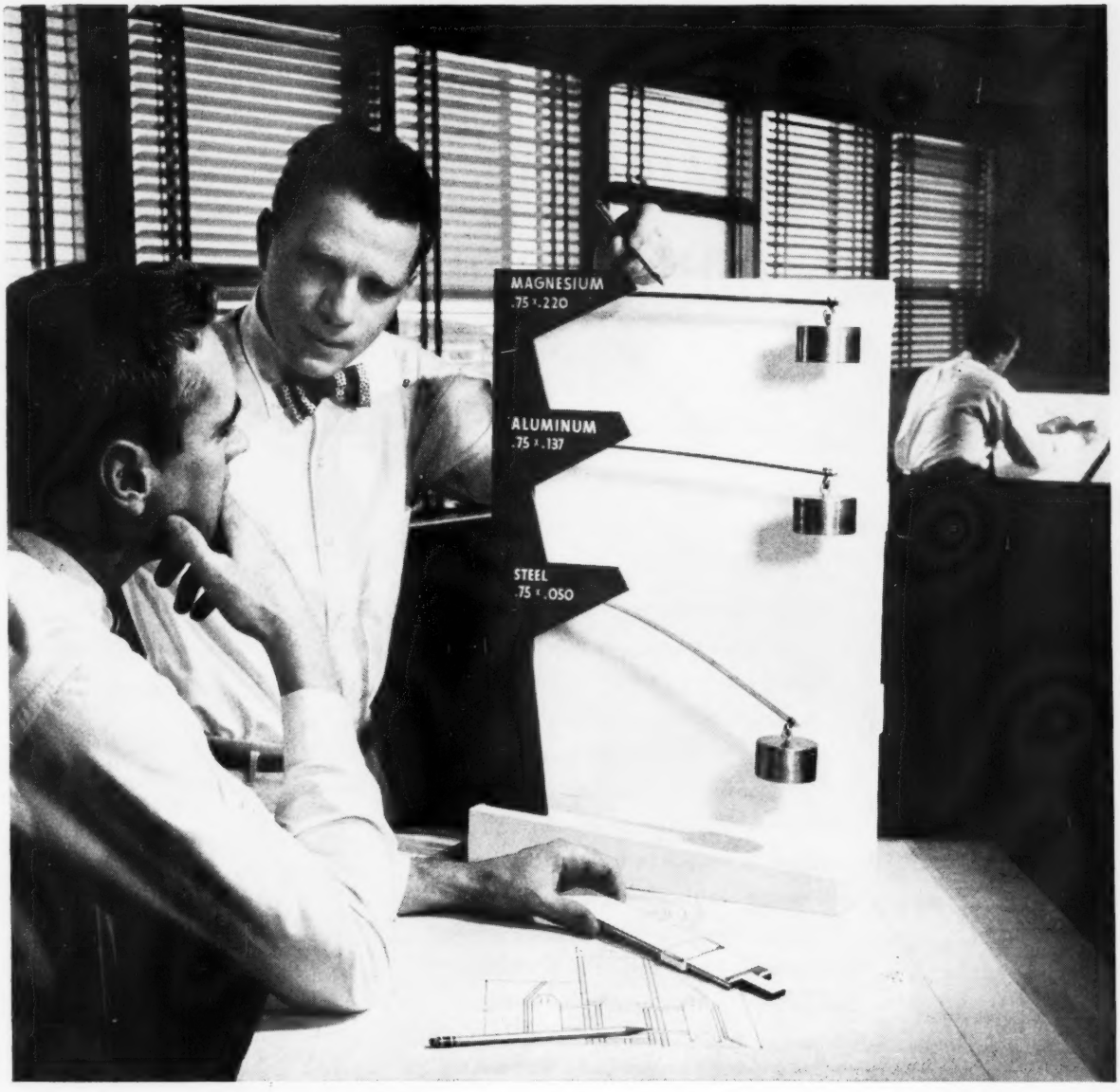

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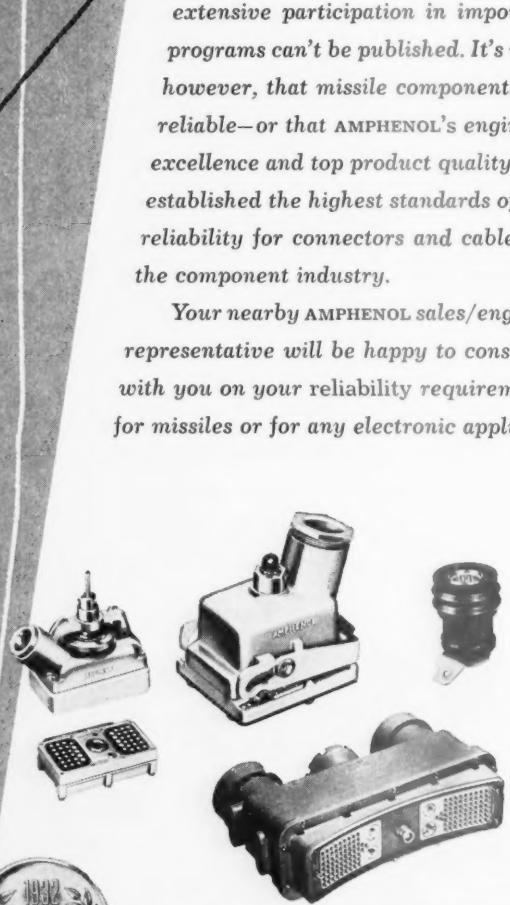

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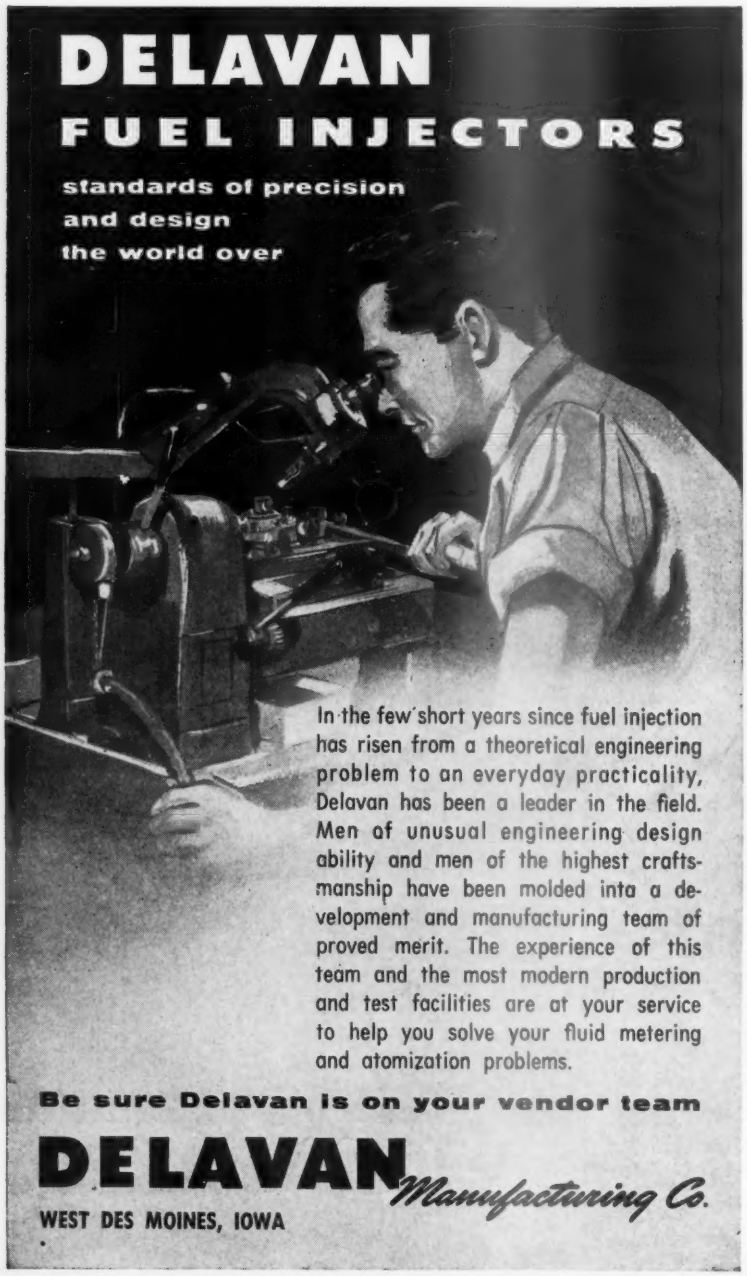
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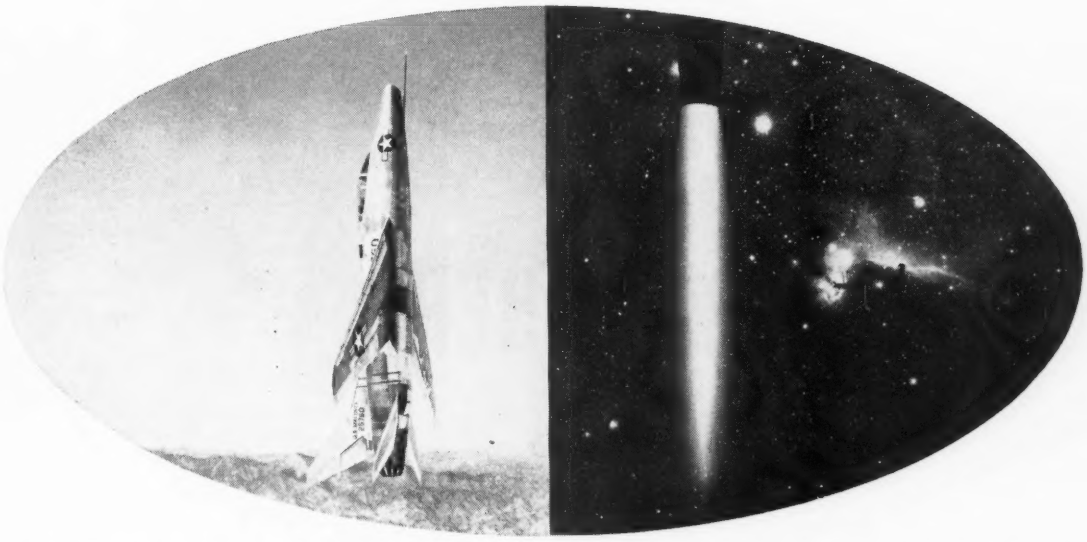

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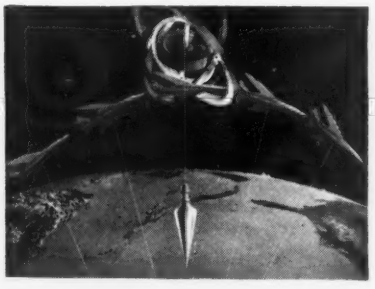

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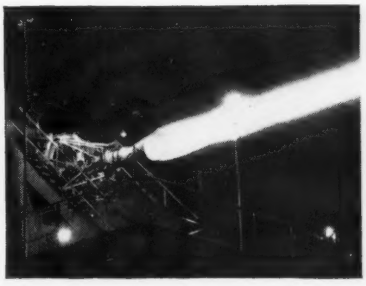

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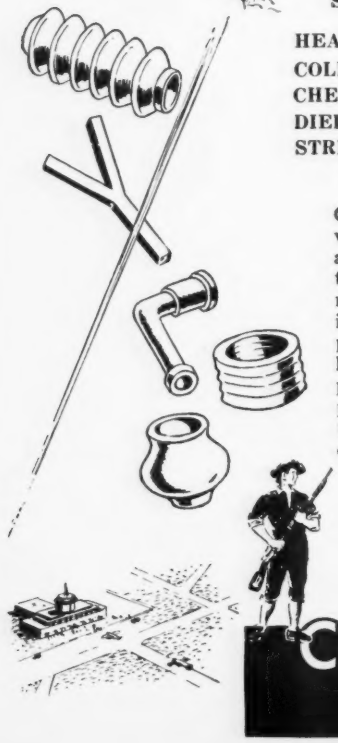

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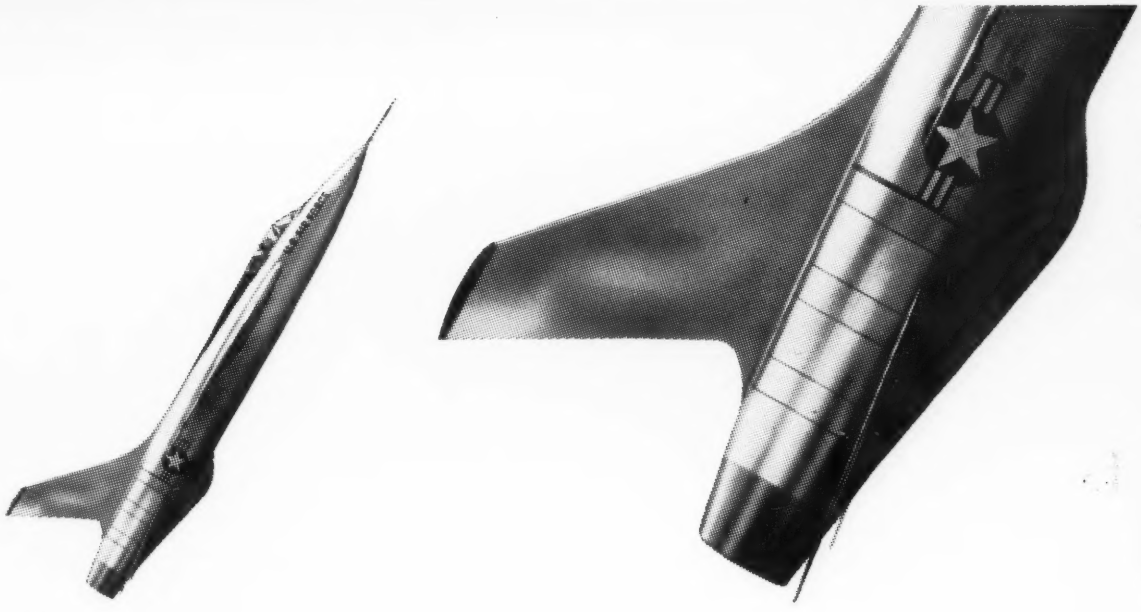

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Wind Tunnels & Research Facilities

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Planned Torture. Forrest Warren. *Ryan Reporter*, June 7, 1957, pp. 19–21, 32. Brief description of the Ryan environmental test center for electronic equipment.

Aperçu Synthétique sur le Problème des Souffleries Transsoniques. L. Rosenthal. *Docaéro*, May, 1957, pp. 3–18. 21 refs. In French. Evaluation of problems encountered during transonic wind-tunnel tests, based on American and British investigations, with suggested solutions and some theoretical and experimental results.

NACA Unitary Plan Wind Tunnels. *Shell Av. News*, May, 1957, pp. 12–14. Description of new high-speed wind tunnels, and of the Langley and Lewis laboratories.

Cornell Laboratory Wave Superheater. T. F. McGarry. *Shell Av. News*, May, 1957, pp. 10, 11. Details of a device which can simulate conditions of 10,000 m.p.h. and 9,000° F. for 15 sec.

On the Errors of a Time Counting System for Use in Experiments with a Shock Tube. Matsunosuke Iwasaki. *J. Japan Soc. Aero. Eng.*, May, 1957, pp. 6–11. 10 refs. Description of a time-counting system with an accuracy of five counts of 1 Mc./sec. pulses. Includes discussion of the development of detached shocks ahead of the 180° and 10° wedge sections of the transonic region.

Magnification Change in Schlieren Systems. George H. Blount and Gene M. Jordan. *IAS J.*, June, 1957, pp. 216–218. Method for determining the lenses which will produce a given magnification change, without repositioning the viewing screen, knife edge, or large mirror.

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Aeronautical Reviews — BOOKS

AERODYNAMICS

Jets, Wakes, and Cavities. Garrett Birkhoff and E. H. Zarantonello. Editing Supported by the Bureau of Ordnance, U.S. Navy. (Applied Mathematics & Mechanics, Vol. 2.) New York, N.Y., Academic Press, Inc., 1957. 353 pp., illus., diagrs., tables. $10.

The present volume is an attempt to report systematically the most important findings of nearly 100 years of research on jets, wakes, and cavities by numerous classical applied mathematicians, pure mathematicians, physicists, and specialists in modern fluid dynamics. The volume is addressed primarily to researchers dealing with problems in hydraulics and aeronautics and takes particular note of the basic advances of the past fifteen years. Since 1940, numerical methods have been revolutionized, a significant theory of axially symmetric jets and cavities has been created, while the fundamental facts about vortex trails and turbulent jets and wakes have been reinterpreted in the light of new concepts. Besides summarizing these major recent advances this book also includes various results of the authors' own work which are here published for the first time. Mr. Birkhoff is affiliated with Harvard University while Mr. Zarantonello is with the Universidad Nacional de Cuyo, Mendoza, Argentina.

Contents: (1) Background and Prospectus. (2) Circular Sector Hodographs. (3) Simple Flows Past Wedges. (4) General Theory. (5) Multiple Plates. (6) Curved Obstacles. (7) Existence and Uniqueness. (8) Compressibility and Gravity. (9) Effective Computation. (10) Axially Symmetric Flows. (11) Unsteady Potential Flows. (12) Steady Viscous Wakes and Jets. (13) Periodic Wakes. (14) Turbulent Wakes and Jets. (15) Miscellaneous Experimental Facts. Bibliography. Plates 1–11. Index.

Hypersonic Gas Dynamic Charts for Equilibrium Air. Saul Feldman. Everett, Mass., AVCO Research Laboratory, AVCO Manufacturing Corporation, January, 1957. 123 pp., diagrs.

This report consists of a collection of charts for air in thermodynamic equilibrium which give information about the state of the gas flowing over bodies at hypersonic speeds in the atmosphere and in shock tubes, and the equilibrium properties of air across normal and oblique shocks, and at a stagnation point. All the results were obtained by using the thermodynamic functions of argon-free air in thermodynamic equilibrium recently published by Hilsenrath and Beckett of the National Bureau of Standards in *AEDC-TN-56-12*, while the data used for the properties of the atmosphere in the flight calculations were taken from *NAVORD Report 1488, Vol. 1, Handbook of Supersonic Aerodynamics*. A Mollier diagram, constructed from the data of the National Bureau of Standards, is also included.

AERONAUTICS, GENERAL

Aviation Facts and Figures, 1957. Official Publication of the Aircraft Industries Association of America. Washington, American Aviation Publications, 1957. 120 pp., illus., diagrs., tables. $1.00.

The fifth edition of this reference work, which represents mainly a compilation of statistics brought up to date as of the end of 1956, covers the following areas: production and facilities, military aviation, guided missiles, research and development, manpower, finance, general aviation, helicopters, air lines and transportation, and United States and foreign aviation exports.

CARTOGRAPHY

Route-Mapping and Position-Locating in Unexplored Regions. Wilhelm Filchner, Erich Przybyllok, and Toni Hagen. New York, N.Y., Academic Press Inc., 1957. 288 pp., illus., diagrs., tables. $9.00.

Success in surveying, mapping, and the determination of geographical points by astronomical observation presupposes that the explorer is thoroughly familiar with many of the techniques and instruments dealt with in this text compiled by three well-qualified authorities on the mapping of unknown territories. For one reason or another, mostly of a political nature, aerial photogrammetry is not always a feasible method for surveying many parts of the world; furthermore, photogrammetric surveys are generally suitable only over large areas so that route-mapping is still an important method for charting small unexplored regions. Dr. Filchner, whose travel and mapping activities span the last half century, discusses the art and science of taking measurements while traveling and propounds a method of map-making which aims at achieving true and realistic descriptions of the countries surveyed while avoiding serious distortions. Professor Przybyllok, writing on position-finding and altitude measurements, introduces the reader to the various astronomical methods employed in determining the exact location of observing stations, and to the instruments and calculations peculiar to these methods. Dr. Hagen's contribution deals with the new tools employed in surveying and cartography today; the aerial photograph and photogrammetry. The systematic use of aerial pictures and terrestrial photogrammetry is shown to offer great advantages in mapping to research expeditions, large or small.

DIRECTORIES

Interavia ABC 1957: Directory of World Aviation. Geneva, Switzerland, Interavia S.A.; New York, N.Y., Interavia U.S.A., 1957. 1,236 pp. $12.

With the 1957 edition of *Interavia ABC*, the publishers have resumed their prewar practice of publishing this complete directory of international aeronautics once each year. Having undergone a 70 per cent revision, the fifth edition is again divided into four major parts that contain 30,000 listings of administrations, organizations, companies and enterprises, 35,000 addresses, and 35,000 names of individuals prominent in all phases of aviation. The ALPHABET is an alphabetical list of civil and military aviation authorities, air lines, aircraft companies, equipment manufacturers, aero clubs, and other types of aeronautical activity. This alphabetical list is cross-referenced to the ANALYT, which provides details of all the preceding activities such as addresses, telephone numbers, cable addresses, executive personnel, products manufactured, and types of aircraft. The INDICATOR is in a five-language glossary of about 1,000 aeronautical terms in English, French, German, Italian, and Spanish. Terms describing aviation products are cross-referenced to key numbers in the ANALYT, thereby enabling the INDICATOR to serve additionally as a Buyer's Guide. WHO IS WHERE is an alphabetical list of the world's senior aviation executives and officers. Each name is provided with a cross-reference directing the user to the appropriate organization in the ANALYT to which the personality in question belongs. The present edition has been corrected, wherever possible, to the end of January 1957 and, unlike previous editions, contains a section on "Eastern Europe" in which information released by the East German Democratic Republic, Poland, Czechoslovakia, and Yugoslavia appears. Information on the Soviet Union, Hungary, Rumania, and Bulgaria was compiled from official publications.

For Information on IAS Library Services, see page 109

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ELECTRICAL ENGINEERING

Electrical Engineering Circuits. Hugh Hildreth Skilling. New York, N.Y., John Wiley & Sons, Inc., 1957. 724 pp., diagrs., tables. $8.75.

A general college course in physics, simple calculus, and complex algebra are the prerequisites for this expository text on a.c. circuits. The material has been repeatedly revised through several years of classroom teaching and is intended to serve the undergraduate student. Fourteen of the twenty-one chapters are allotted to the standard subject matter of electrical engineering texts. The remainder are devoted to discussions of the more modern concepts such as: network theorems, loop and node equations of networks, locus curves and other graphical methods, resonance of high-Q circuits, impedance and admittance functions, poles and zeros in the complex frequency plane, the transform concept, and the Laplace transformation. Dr. Skilling, Professor of Electrical Engineering, Stanford University, ends each chapter with a summary and a set of graded problems.

ELECTRONICS

Proceedings of the Second RETMA Symposium on Applied Reliability, Syracuse, N.Y., June 10–11, 1957. Sponsored by the Engineering Department of the Radio-Electronics-Television Manufacturers Association. Engineering Pub-

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lishers, G.P.O. Box 1151, New York 1, N.Y., 1957. 93 pp., illus., diagrs., tables. $5.00.

Contents: Selection and Use of Components in Mature Design: Components in Project "Sure," H. E. Bernstein. Application Evaluation of Electronic Parts, Garland L. Tomlin, Sr., and William A. Barron. Relays as Reliable Electronic Components, Walter F. Schuchard. *Principles and Techniques of Mature Mechanical Design:* The Achievement of Reliability in Military Equipment, L. M. Clement. Target—Reliability, L. R. Zimov and P. F. G. Holst. Mechanical Design Features of a Radar for the Military Services, L. Jacobs. Plug-In Units as an Aid for Reliability, R. B. Bonney. Procedures Towards Achieving Mature Design, R. E. Clark. *Measurement and Proof of Mature Design:* Reliable System Design, M. M. Tall and S. M. Sherman. Failure Prediction Techniques for Radar Design, F. L. Scripture. Engineering in Reliable Design, E. R. Jervis. *Case Histories of Mature Equipment and Systems:* Reliability Measurement of Mature Design, Richard R. Landers. The AN/FSQ-7: A Reliability Progress Report, H. E. Cooley and R. E. Nienburg. The APN-70, J. P. Eugley. TACAN, The RT-220/ARN-21, E. F. Peacox.

1957 Proceedings of the National Conference on Aeronautical Electronics, May 13-15, 1957, Dayton, Ohio. Sponsored by Institute of Radio Engineers, Dayton Section and Professional Group on Aeronautical and Navigational Electronics; Participation by the Institute of the Aeronautical Sciences. National Conference on Aeronautical Electronics, P.O. Box 621, Far Hills Branch, Dayton, Ohio, 1957. 409 pp., illus., diagrs., tables. $4.00.

Contents: Equipment Applications I: Operation of an Electronic Component Part Application Unit, J. P. Francis. Component Application Engineering at RCA, Richard H. Baker. Management Support of Component Application Organizations, James H. Allen. The Electronic Component Part Group at Northrop and its Contribution to Reliability, B. D. Johnston. Establishment and Results of a Comprehensive Component Reliability Program, Charles G. Wallance. *Component Parts—Vacuum Tubes:* The Wamoscope—A New Microwave Display Device, R. G. E. Hutter, L. R. Bloom, D. E. George. A 300 Watt Stacked Ceramic Tetrode for Ground and Airborne Transmitters, Willis B. Foote. Vacuum Tubes for 500°C Envelope Bulb Temperature and High Vibration Environment, John H. Wyman, R. H. Kuhnapfel. The Amplitron, A Broadband Amplifier Application of a New Microwave Tube Principle, William C. Brown. A C-W UHF TWT Power Amplifier of Extended Bandwidth, Ward A. Harman. Backward Wave Oscillators for the 17 to 41 kmc./sec. Band, J. A. Noland, R. E. Lepic. A Half Tone Display Storage Tube with Magnetic Deflection, M. E. Craig. *Navigation I:* Application of Automatic Dead Reckoning Equipment to Current Problems of Air Navigation, H. R. Walcott Precision Azimuth Reference Systems, Albert Shapiro. Doppler Navigation, William J. Tull. Self-Contained Navigation Aids and the Common System of Air Traffic Control, Nathaniel Braverman. *Equipment Applications II:* The Evolution of a Punched Card Coordinate Indexing System for Use in Parts Evaluation and Application, Arthur J. Chippendale, Jr. Component Design and Development to Meet Advanced Application Requirements, Ted A. Thompson. An Airborne Atomic Frequency Standard, J. J. Bagnall, J. H. Holloway. A One-Kilowatt Airborne Radio-Frequency Power Amplifier, James B. Humfeld. Depot Test Equipment Concepts, David B. Dobson. Some Design Factors for the Magnetron-Isolator Combination, Ray A. Krogh. *Communications:* Some New Horizons in Communications, George H. Sheer. The Synchronous Detector, Raymond J. Lutze. Basic Kineplex Principles and Applications, P. J. Icenbice, Jr. Labil Light Aircraft Binary Information Link, R. J. Ertman, W. F. Walker. Some Aspects of Digital Data Transmission, Siegfried Reiger. The Tacan Data

Link, R. C. Renick. *Electronic Equipment:* The New All-Electronic Indicator for Aircraft Application, John R. Bethke. Compensation Network Design as Applied to Transistor Feedback Amplifiers, T. Eugene Smith. The Design of Transistorized Intercommunication Systems for Military Aircraft, Guy S. Rambie, Jr. A High Performance Transistor-Regulated Power Supply, Thomas A. Weil, Ben Erdman. Biased Chokes for Improved Swinging Choke Action, Thomas A. Weil. The Valentine Antenna, Edwin M. Turner. *Navigation II:* Some Aspects of Vortac, Sven H. Dodington. Radio Position Fixing by Low Frequency Composite Wave Measurements, B. Alexander, S. Hyman. Delrac—A Long-Range Aid to Navigation, D. H. Toller-Bond. Light Weight Digital Computers, John M. Mayer. Position Fixing by Means of Low Frequency Ground Wave Phase, Winslow Palmer. *Management I—Research:* Planning of Research Work at Westinghouse Electric, Clarence Zener. The Project Overlay System of Research Organization, Robert M. Bowie. Teamwork in Research, Rudolf Kompfner. Measurement of Research Results, Lyman R. Fink. The Climate of University Research, Carl W. Gartlein. *Environment I:* Integration of Crew and Equipment Cooling in Supersonic Bomber Design, A. E. Hitsman. Cooling Airflow Control Systems for Airborne Electronic Equipment Designed for Efficient Use of Refrigerated Air, L. H. Schreiber, H. R. Wesson. Indirect Liquid Cooling Compared with Direct Air Cooling for an Airborne Electronic System Component, Kenneth J. Fawcett. High-Reliability Thermal Design for Commercial Avionics, Harry M. Passman. Methods of Determining the Thermal Condition of Glass Electron Tubes, J. P. Welsh. *Air Safety:* The Challenge of Air Safety, Jerome Lederer. Words of Caution Regarding Any Air Safety Program, K. C. Black. Air Force Considerations in Collision Avoidance, S. A. Segen. The Communication Requirements of Common System Air Traffic Control, Milton W. Arnold. Safety Provided by the Future Air Traffic Control System, Gordon C. Dewey. Problems in Airborne Communications, J. D. Smith. *Component Parts—Miscellaneous:* High Temperature (500°C.) Capacitor, Roger L. Faust, G. W. Monk, David Wm. Moore. Some Considerations in the Measurement of Capacitor Insulation Resistance, F. W. Grahame. High Temperature Film Resistors, E. M. Griest. Failure Rate Measurements by Means of Accelerated Tests, I. K. Munson. Pulse Transformer Insulator Application, W. A. Ernst. *Management II:* Management of a Dispersed Research and Development Facility, Thomas Meloy. Research Center in an Institute of Technology, J. E. Boyd. Centralized or Decentralized Program Planning, E. G. Fubini. Should Contract R & D Yield a Competitive Return on Stockholders' Investment?, John F. Byrne. *Environment II:* Improved Equipment Design with Forced-Air and Liquid Cooling, Walter Robinson. Heat Exchange System Design for Airborne Electronic Equipment, F. P. Behning, J. P. Jacob. Design of Liquid-Filled Containers for High-Voltage Equipment, T. P. Jordan. Effect of Submerged Liquid Cooling on the Electronic Performance of Several Common Types of Electronic Circuits, K. R. Vincent, G. W. Millsap. Temperature Control Design of the Airborne Bombing and Navigation System AN/ASB-4, Beal Marks, J. J. Students, R. M. Dailey, R. W. Hook. *Management III—Production:* Production Management—The Engineering Manager, J. W. Giles. Low Volume Production of Complex Systems, I. B. Anthony. Preproduction Engineering Starts with Research and Development, Leon Himmel. Management Problems in Engineering—Production Relations for a Crash Program, H. K. Hudson. *Component Parts—Semi-Conductors:* Medium Power Silicon Transistors, R. W. Aldrich, M. Waldner. An Analysis of the Effect of Nuclear Radiation on Transistors, J. J. Loferski. The Unijunction Transistor—What It Is and What It Does, S. R. Brown. High-Frequency Germanium Transistors, N. H.

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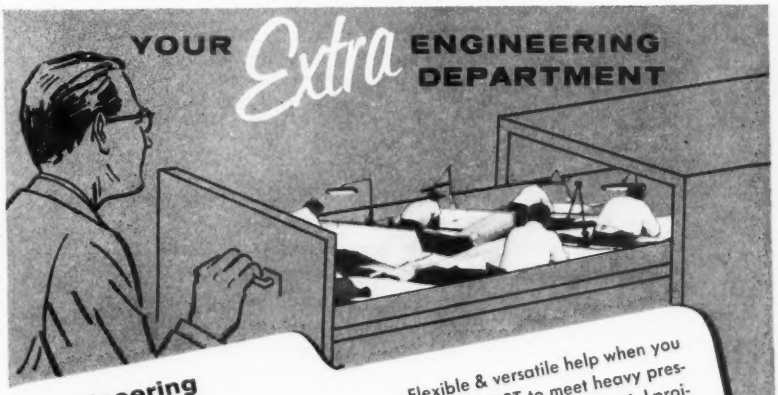

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Ditrick. High Voltage Silicon Rectifiers, Jay W. Thornhill, James S. LaRue. A 5-Watt, 10-Megacycle Transistor, J. T. Nelson, J. E. Iwersen, F. Keywell. *Environment III:* A Method of Packaging Transistorized Printed Circuit Board Assemblies for Efficient Use of Refrigerated Air, H. Kamei, A. R. Tice. Technical Note on an Expendable Liquid Evaporative Cooling System, Walter W. Hagner. Forced Air Cooling for Power Transistors, Melvin Mark. Cross-Flow Cooling of Sealed Electronic Modules, Charles D. Jones. Cooling of Electronic Equipment by Means of Heavy Inert Vapors, J. F. Ahearn, R. R. Ursch, L. F. Kilham, Jr.

MATHEMATICS

Applied Analysis. Cornelius Lanczos. Englewood Cliffs, N.J., Prentice Hall, Inc., 1956. 539 pp., diagrs., tables. $9.00.

The topics considered in each chapter of this study of the various branches of analysis are encountered almost daily by the engineer and the physicist. The volume concerns itself primarily with the analysis and design of finite processes which approximate the solution of an analytical problem and with the design of procedures which will effectively minimize the error in a small number of steps and which will estimate the error with sufficient accuracy. The author is Senior Professor, School of Theoretical Physics, Dublin Institute for Advanced Studies.

Contents: (1) Algebraic Equations. (2) Matrices and Eigenvalue Problems. (3) Large-Scale Linear Systems. (4) Harmonic Analysis. (5) Data Analysis. (6) Quadrature Methods. (7) Power Expansions. Appendix: Numerical Tables. Index.

The Hypercircle in Mathematical Physics; A Method for the Approximate Solution of Boundary Value Problems. J. L. Synge. Cambridge, Eng., at the University Press; New York, N.Y., Cambridge University Press, 1957. 424 pp., diagrs. $13.50.

This book gives a systematic and unified approach to a wide class of problems, based on the fact that the solution may be viewed as a point in function-space, this point being the intersection of two linear subspaces orthogonal to one another. In this way the solution is located on a hypercircle in function-space, and the approximation can be improved by reducing the radius of the hypercircle. The inevitable complexities of calculation (by finite differences or otherwise) are illuminated throughout by simple intuitive geometrical pictures, and the error at any stage is accurately assessed by the radius of the hypercircle.

Elementary ideas of function-space are developed from first principles, and no highly specialized mathematical knowledge is required of the reader. Illustrative numerical examples are worked out in detail with special emphasis on the torsion problem. Although comparatively elementary, the mathematics is precise, and for that reason the book should interest mathematicians as well as physicists and engineers.

Dr. Synge is Senior Professor, School of Theoretical Physics, Dublin Institute for Advanced Studies, and has taken 10 years to evolve this work, during which time he has given lectures and short courses on various aspects of the subject matter in universities throughout the United States and Europe.

Vector Analysis. Louis Brand. New York, N.Y., John Wiley & Sons, Inc., 1957. 282 pp., diagrs. $6.00.

The fundamental theory of vector analysis, which is becoming of greater use to the mathematician, physicist, and engineer, is presented in an elementary treatment that introduces the student to the tools of vector algebra and calculus, and affords a brief glimpse of their manifold applications in statics, dynamics, fluid mechanics, and electrodynamics. All theory is illustrated by examples and supplemented with numerous problems, many of which have hints for solution. Exposition is given to such topics as analytical and graphical line vectors, differential invariants and integral theorems, with

applications to mathematical physics; Green's identities and their application to potential theory; a logical development of electrodynamics based on Maxwell's equations and using m.k.s. units; and abstract vector spaces, including the Hilbert space. Dr. Brand is Professor Emeritus of Mathematics, University of Cincinnati, and Whitney Visiting Professor, Trinity College.

Plane Waves and Spherical Means Applied to Partial Differential Equations. Fritz John. (Interscience Tracts in Pure and Applied Mathematics, No. 2.) New York, N.Y., Interscience Publishers, Inc., 1955. 172 pp., diagrs. $4.50.

This tract contains a somewhat heterogeneous collection of results on partial differential equations. The unifying element is the use of certain elementary identities for plane and spherical integrals of an arbitrary function. It is the aim of the author, who is with the Institute of Mathematical Sciences, New York University, to show how a variety of results on fairly general differential equations follows from those identities.

Contents: (1) Decomposition of an Arbitrary Function into Plane Waves. (2) The Initial Value Problem for Hyperbolic Homogeneous Equations with Constant Coefficients. (3) The Fundamental Solution of a Linear Elliptic Differential Equation with Analytic Coefficients. (4) Identities for Spherical Means. (5) The Theorems of Asgeirsson and Howard. (6) Determination of a Function from its Integrals over Spheres of a Fixed Radius. (7) Differentiability Properties of Solutions of Elliptic Systems. (8) Regularity Properties for Integrals of Solutions over Time-Like Lines.

An Introduction to the Theory of Numbers. I. M. Vinogradov. Translated by Helen Popova from the 6th Russian Edition, 1952. London, New York, Pergamon Press, 1955. 155 pp., tables. $1.75.

In this first authorized translation into English of a work by a prominent Russian mathematician, a systematic study of the properties of integers is presented in six chapters of text which deal with the theory of divisibility, fundamental functions of the theory of numbers, congruences, linear congruences, quadratic congruences, and primitive roots and indices. The author, who is a Member of the Academy of Sciences, U.S.S.R., has included a selection of problems and their solutions.

METALS & ALLOYS

Boron, Calcium, Columbium, and Zirconium in Iron and Steel. R. A. Grange, F. J. Shortsleeve, and D. C. Hilty, W. O. Binder, G. T. Motock, and C. M. Offenhauer. (Alloys of Iron Research, Monograph Series, Published for the Engineering Foundation.) New York, N.Y., John Wiley & Sons, Inc., 1957. 533 pp., illus., diagrs., tables. $14.

This volume is a collection of four separate short monographs on four of the elements used as alloying metals with iron and steel: boron, calcium, columbium, and zirconium. *Part 1* presents the engineering properties and fundamental aspects of boron, its effect on heat-treating characteristics, and its use in ferrous alloys other than constructional steels. *Part 2* describes deoxidation and desulphurization by calcium, and its application in steel and cast iron. *Part 3* gives the preparation and properties of columbium, and its effects in various combinations of alloys and steels. *Part 4* details the extraction from ore and the properties of zirconium, plus its effects in cast iron, steel, and other alloys used in steelmaking. The monographs were written by authorities in the field and collect in a single binding the scattered published and unpublished data on these important alloying metals so as to ease the burden of research on the metallurgist and engineer. Each monograph is supplemented with an extensive chronological bibliography.

NAVIGATION

Radio Aids to Air Navigation. J. H. H. Grover. New York, N.Y., Philosophical Library, Inc., 1957. 138 pp., illus., diagrs. $6.00.

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A basic knowledge of navigational principles on the part of the reader is assumed by the author, for it is outside the scope of this volume to enter into navigation theory except where it directly concerns the radio aspect of the matter. Mr. Grover does not consider it necessary for the average aircrew member to know detailed technical aspects of the aids he is likely to use in radio navigation so consequently lays greater stress upon performance, capabilities, and methods of operation, taking as his guide the British Ministry of Transport and Civil Aviation Licence requirements for air-line pilots and navigators. The more important of the present-day systems are discussed; military equipment has been deliberately ignored since the whole purpose of this book is to provide students, reading in preparation for their civil license examinations, the basic knowledge required in this respect as regards radio aids to navigation.

Contents: (1) Introduction and General Principles. (2) Medium-Frequency Systems. (3) More Advanced MF Aids. (4) VHF Systems. (5) Hyperbolic Aids—I. (6) Hyperbolic Aids—II. (7) Pulse Systems. (8) Aids to Air Traffic Control. (9) Aids to Approach and Landing. (10) Future Aids and Trends. (11) Charts, Documents, and Regulations. Appendix A: Table of Radio Aids. Appendix B: Formulae and Conversion Factors. Index.

OPERATIONS RESEARCH

Introduction to Operations Research. C. West Churchman, Russell L. Ackoff, and E. Leonard Arnoff. New York, N.Y., John Wiley & Sons, Inc., 645 pp., diagrs., tables. $12.

As a scientific activity, operations research began in a military context, but its evolution or emergence can best be described in terms of the well-known development of industrial organization. In a general sense operations research can be characterized as the application of scientific methods, techniques, and tools to problems involving the operations of systems so as to provide those in control of the operations with optimum solutions to the problems. This introductory text restricts itself to the application of operations research to executive-type problems in organization.

The text grew from the lecture material for the "Short Course in Operations Research," which has been offered annually since 1952 by Case Institute of Technology. Aimed at both the prospective consumer and practitioner, an attempt has been made to simplify the technical material without distorting it, and particular emphasis has been placed upon the creation of a thorough understanding in the reader of the application of scientific method to operations research rather than on the numerous techniques available to the experienced practitioner. Although the chapters of this book were initially prepared by different persons, the authors have completely rewritten many of the chapters and have very extensively revised others, bringing to the work their own wide knowledge and experience. All three are on the faculty of Case Institute of Technology and are members of the Institute of Management Sciences and fellows of the Operations Research Society of America.

Contents: Part 1, Introduction: (1) The General Nature of Operations Research. (2) An Operations Research Study of a System as a Whole. (3) Research Team Approach to an Inspection Operation. *Part 2, The Problem:* (4) Analysis of the Organization. (5) Formulation of the Problem. (6) Weighting Objectives. *Part 3, The Model:* (7) Construction and Solution of the Model. *Part 4, Inventory Models:* (8) Elementary Inventory Models. (9) Inventory Models with Price Breaks. (10) Inventory Models with Restrictions. *Part 5, Allocation Models:* (11) Linear Programming. (12) The Assignment Problem. (13) Some Illustrations of Allocation Problems. *Part 6, Waiting-Time Models:* (14) Queuing Models. (15) Traffic Delays at Toll Booths. (16) Sequencing Models. *Part 7, Replacement Models:* (17) Replacement Models. *Part 8, Competitive Models:* (18) The Theory of Games. (19) Bidding Models. *Part 9, Testing, Control, and Implementation:* (20) Data for Model Testing. (21) Controlling and Implementing the Solution. *Part 10, Administration of Operations Research:* (22) Selection, Training, and Organization for Operations Research. Author Index. Subject Index.

PHYSICS

Physics of Fully Ionized Gases. Lyman Spitzer, Jr. (Interscience Tracts on Physics and Astronomy, No. 3.) New York, N.Y., Interscience Publishers, Inc., 1956. 105 pp., diagrs., tables. $3.50.

Designed for those who have had an introductory course in theoretical physics but are otherwise unacquainted with the detailed kinetic theory of gases, this monograph presents the theory of macroscopic motion, of collisions, and of electromagnetic, magnetohydrodynamic, and electrostatic waves in a fully ionized plasma. A knowledge of Maxwell's equations is assumed and likewise a familiarity with the elements of vector analysis. The author is Director of the Princeton University Observatory, Princeton, N.J.

Light Scattering by Small Particles. H. C. van de Hulst. New York, N.Y., John Wiley & Sons, Inc., 1957. 470 pp., diagrs., tables. $12.

This book has a single theme, the scattering of light, and is divided into three parts which treat three distinct phases of the subject. Part I gives general theorems for particles that may have arbitrary size, shape, and composition; Part II, comprising the major portion of the work, specifies the amplitude functions for a great variety of special particles; and Part III presents selected applications in many areas of chemistry, physics, meteorology, and astronomy. There are three subject limitations: only a few of the multitude of scattering phenomena are treated; scattering by

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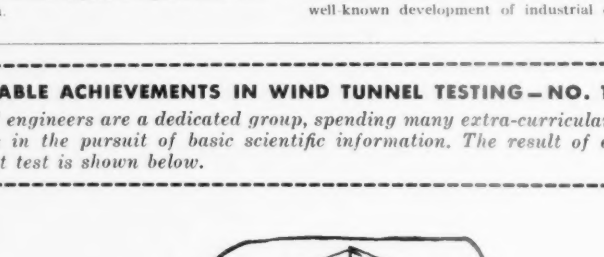

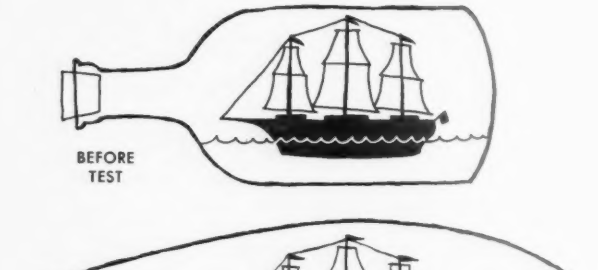

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independent particles only is dealt with; and concentration has been accorded the phenomena of single scattering, to the neglect of multiple scattering. The author, with the Leiden Observatory, the Netherlands, has based his arguments on physical intuition wherever they appear more lucid than mathematical derivation.

SAFETY

Safety After Solo; How to Fly 10,000 Hours. John R. Hoyt. 2nd Rev. Ed. North Hollywood, Calif., Pan American Navigation Service, Inc., 1957. 364 pp., illus., diagrs., tables. $4.75.

This is essentially a warning to all aviators, beginners and veterans alike, that there is no substitute for good judgment in the air. The author's aim is to reduce the periods in a pilot's life when overconfidence or sheer flaunting of the rules are most apt to put a sudden and unexpected end to his flying career. Safety is the main theme of this book which attempts to make very clear that the successful airman is not necessarily always the "hot" pilot or the quickest learner, but he who adapts himself through recognition of his shortcomings and through his ability to avoid repetition of his errors. Mr. Hoyt is a former Commander in the U.S. Naval Reserve and has served as an inspector for the Civil Aeronautics Administration.

SPACE TRAVEL

Rockets, Missiles, and Space Travel. Willy Ley. Rev. Ed. New York, N.Y., Viking Press, 1957. 528 pp., illus., diagrs., tables. $6.75.

This revision is an enlargement of the 1951 edition. The chapter on war rockets has been expanded and details the success of large and reliable powerful solid-fuel charges. The story of the Peenemünde Rocket Research Institute of the German Army is now complete. Information has become available also to complete the histories of the V-2 Program at the White Sands Proving Ground, the Navy's Viking Program, and the research and development of a host of rockets including the Aerobee, the Rockoon, the Aerobee-Hi, the Nike-Deacon, and the Terrapin. The last two chapters on space travel reflect the change in attitude and concept that have evolved and culminated in the satellite program, Project Vanguard. The Appendix has been expanded to 88 pages of notes and tables; and the Bibliography has tripled to include some 500 items.

Realities of Space Travel: Selected Papers of the British Interplanetary Society. Edited by L. J. Carter. London, Putnam & Company, Ltd., 1957. 431 pp., illus., diagrs., tables. 35*s*.

For many years the British Interplanetary Society has published a bimonthly journal in which numerous original papers have appeared, many by the sixteen contributors to this newly compiled volume. Certain of these papers have been selected by Mr. Carter, Secretary of the B.I.S., and grouped under ten major headings to provide an illuminating and comprehensive survey of space travel, its history, and its probable future.

Contents: (*1*) *Introduction to Astronautics:* Basic Principles of Astronautics, L. R. Shepherd. The Dynamics of Space Flight, A. C. Clarke. Rocket Engines and Propellants, A. V. Cleaver. Mass Ratios, A. V. Cleaver. The Calculation of Take-Off Mass, A. V. Cleaver. (*2*) *The Satellite Vehicle:* Minimum Satellite Vehicles, K. W. Gatland, A. M. Kunesch, and A. E. Dixon. A Minimum Orbital Instrumented Satellite—Now, S. F. Singer. Descent from Satellite Orbits Using Aerodynamic Braking, T. Nonweiler. (*3*) *Interplanetary Flight:* Some Limiting Factors of Chemical Rocket Motors, W. N. Neat. The Atomic Rocket, L. R. Shepherd and A. V. Cleaver. Interorbital Transport Techniques, H. Preston-Thomas. The Determination of Minimal Orbits, D. F. Lawden. (*4*) *Physical Factors in Space Flight:* Meteor Hazards to Space Stations, M. W. Ovenden. The Possibility of Cosmic Ray Hazards in High Altitude and Space Flight, L. R. Shepherd. (*5*) *Biological Aspects of Space Flight:* Aeromedical and Biological Considerations of Flight above the Atmosphere, P. A. Campbell. Sensory Perceptions of the Weightless Condition, A. E. Slater. The Food and Atmosphere Control Problem on Space Vessels, N. J. Bowman. (*6*) *Targets for Tomorrow:* What We Know about the Moon, P. Moore. The Planet Mars, P. Moore. (*7*) *The Development of Astronautics:* A Programme for Achieving Interplanetary Flight, A. V. Cleaver. (*8*) *Establishments and Testing Station:* U.S. Naval Ordnance Test Station at Inyokern, L. J. Carter. Anglo-Australian Rocket Testing Range, L. J. Carter. (*9*) *History of Astronautics:* European Rocketry after World War I, Walter R. Dornberger. (*10*) *The Distant Future:* Interstellar Flight, L. R. Shepherd. (*11*) *Appendices:* The British Interplanetary Society, List of Astronautical and Rocket Societies. Name Index. Subject Index.

THERMODYNAMICS

Thermodynamics; An Advanced Treatment for Chemists and Physicists. E. A. Guggenheim. 3rd Ed. Amsterdam, North-Holland Publishing Company; New York, N.Y., Interscience Publishers, Inc., 1957. 476 pp., diagrs., tables. $9.75.

Two major changes appear in the present edition of a work last published in 1950. A short chapter, confined to isothermal systems, has been included on Onsager's relations, without, however, application to coupled chemical reactions under conditions close to equilibrium. With respect to the treatment of mixtures a special chapter on "mixtures" has been added in which all components are treated on a par with the emphasis on mole fractions, and a chapter on "solutions" in which one component is singled out as the solvent with the emphasis on mole ratios or molalities.

VIBRATION

Mechanical Vibrations. Bernard Morrill. New York, N.Y., The Ronald Press Company, 1957. 262 pp., diagrs., tables. $6.50.

This treatment of mechanical vibrations has been written to serve as an introductory text for the undergraduate or graduate student who is adequately grounded in integral calculus. Three different approaches are accented in determining the equations of motion for a vibratory system, the Newtonian and energy approaches for relatively simple systems, the Lagrangian approach for complex systems. The eight chapters deal with dynamics of a particle, mathematics of a system of a single degree of freedom, single degree of freedom, systems with several degrees of freedom, beams and shafts, Lagrange equations, vibration in a continuous medium, and miscellaneous topics. Material covered includes such topics as linear differential equations, partial derivatives, partial differential equations, electrical analogy, the mobility method, and an elementary discussion of the analog computer. The author has based the treatise on his teaching experience as Associate Professor of Mechanical Engineering, Swarthmore College.

WIND TUNNELS

Mach Number Measurements in High-Speed Wind Tunnels. J. A. F. Hill, J. R. Baron, L. H. Schindel, and J. R. Markham. (AGARDograph No. 22.) Paris, NATO AGARD, October, 1956. 113 pp., diagrs., tables. Distributed in the United States by NACA, Washington.

Measurements of subsonic and supersonic Mach Numbers in air are treated from the point of view of calibration measurements of an empty wind tunnel, of measurements of local Mach Numbers at points in the flow field around a model, and of simulating free flight Mach Number in the presence of wind-tunnel wall interference. Errors in deducing Mach Number from particular measurements are also discussed, and certain measuring procedures are recommended.

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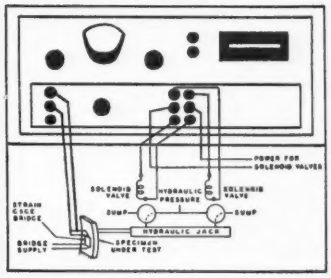

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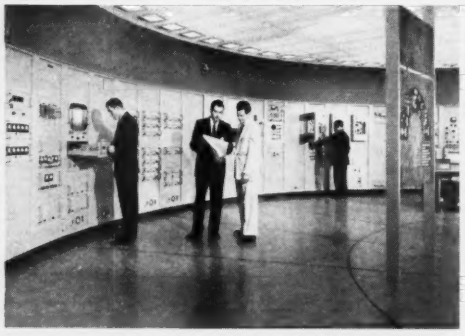

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Acoustics Engineer—Master's degree or equivalent in technical experience. U.S. citizen preferred. Will be conducting research on noise problems and measuring techniques for sound reduction. Will direct and be responsible for entire accoustical program. **Metallurgist**—Master's degree or equivalent in technical experience. Will be responsible for entire Metallurgical Program which includes research on heat treating and manufacturing processes. Send résumé to: Technical Placement Supervisor, Department DW, Cessna Aircraft Company, 5800 East Pawnee Road, Wichita, Kansas.

Aeronautical and Mechanical Engineers and Electronic Scientists—The Flight Test Division of the Naval Air Test Center has openings for aeronautical and mechanical engineers at grades GS-5 to GS-12 levels, salaries from $4480 to $7570 per annum, and electronic scientists at grades GS-5 to GS-11, salaries from $4480 to $7035 per annum. The Flight Test Division is engaged in the evaluation of new navy fighter aircraft, high speed flying boats, and all types of helicopters. Work includes performance, stability and control, carrier suitability, and hydrodynamics. The incorporation of automatic data handling systems and telemetering techniques has increased the divisional needs for electronic engineers. The work is closely associated with the aircraft development work of the majority of the major aircraft manufacturers of the country. Visits to major air installations throughout the country are a routine part of this engineering work and tests are conducted regularly aboard the Navy's newest aircraft carriers. Opportunity exists for both the experienced engineers and the recent graduates. In several positions, piloting background is desirable. Send a résumé to the Chief Engineer, Flight Test Division, Naval Air Test Center, Patuxent River, Maryland.

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Engineers and Draftsman—Manufacturer of executive transport aircraft has immediate openings in the following categories: liaison engineer, systems engineer, aerodynamics engineer. Minimum experience three years. Openings also for chief draftsman (four years' minimum experience) and draftsmen (one year minimum). Contact G. E. Ransleben, Jr., Aircraft Engineering Supervisor, Howard Aero Inc., Mfg. Div., P.O. Box 8247, San Antonio 12, Texas.

Aeronautical Engineer or Mechanical Engineer—Must have mechanical design working experience. Knowledge of aerodynamics and propulsion also required. Project Head status with salary based on background. Location in New York City. Forward résumé to Box 551, G.P.O., New York 1.

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Electronic Scientists, Metallurgists, Physicists, Technologists and Engineers (Aeronautical, Electrical, Electronic, Industrial, General, Mechanical, and Power Plant—The Naval Air Material Center, Philadelphia 12, Pa., has an urgent need for qualified engineering and scientific personnel to fill vacancies in the above positions. The Center is currently engaged in an extensive program of aeronautical research development, experimentation, and test operations for the advancement of Naval aviation. Starting salaries range from $4,480 to $7,570 per annum. Application for Federal Employment, Standard Form 57, should be filed with the Industrial Relations Department, Naval Air Material Center, Naval Base, Philadelphia 12, Pa. Applications may be obtained from the above address or information as to where they are available may be obtained from any first- or second-class post office.

Air Technical Intelligence Specialist (Aerodynamics), GS-12—A critical vacancy exists at the Air Technical Intelligence Center for an Air Technical Intelligence Specialist (Aerodynamics), GS-12, $7,570.00 per annum. The purpose of this position is to produce finished intelligence estimating foreign research and development capabilities in the specialty field of theoretical and applied aerodynamics. Applications should be addressed to Commander, Air Technical Intelligence Center, Attn.: AFOIN-4X2b, Wright-Patterson AFB, Ohio.

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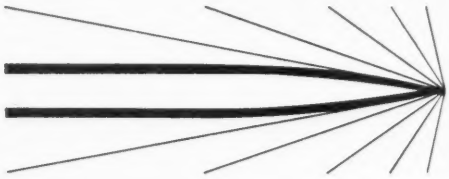

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FLIGHT TEST ENGINEERING SECTION, which plans the missile test programs and establishes test data requirements in support of the programs. The data requirements are predicated on the test information required by the engineering analytical and design groups to develop and demonstrate the final missile design, and are the basis from which instrumentation requirements are formulated.

The analysis work performed consists of aerodynamic, missile systems, dynamics, flight control, propulsion and guidance evaluation. The Flight Test Engineering Section is also responsible for the field test program of the ground support equipment required for the missile.

FLIGHT TEST INSTRUMENTATION SECTION, which includes a Systems Engineering Group responsible for the system design concept; a Development Laboratory where electronic and electro-mechanical systems and components are developed; an Instrumentation Design Group for the detail design of test instrumentation components and systems; a Mechanic Laboratory where the instrumentation hardware is fabricated; and a Calibration and Test Group where the various instrumentation items and systems are calibrated and tested.

For 17 years Northrop Aircraft has pioneered in missile research and development. As a member of this forefront organization in this growing field, new opportunities for full expression of your initiative and ability will always be yours at Northrop.

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EMPLOYMENT PROSPECTUS

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Type of work: Principally applied research, with complementary activity in both basic research and development. Current C.A.L. projects deal with almost every area of research related to modern and future flight including: aerodynamics, gasdynamics, propulsion, full scale flight research with variable stability aircraft, and wind tunnel research from subsonic to hypersonic. Still other C.A.L. projects include the study of aeroelastic phenomena, advanced missile and aircraft design, and air traffic control studies.

Description of Organization: C.A.L. is a not-for-profit corporation wholly owned by Cornell University. It is financially self-supporting, and operated for the purpose of advancing and enlarging scientific and engineering knowledge. Toward this end, the value of research completed last year rose to 14 million dollars, the 7th consecutive annual increase. C.A.L. has 1150 employees.

Desirable features of employment at C.A.L.: VARIETY — the 400 engineers and scientists at C.A.L. are working in 11 technical departments, which last year completed 180 projects, both large and small. INDIVIDUAL RECOGNITION — the high ratio of contracts per engineer, coupled with the Laboratory's practice of using small research teams, allows the recognition of every man's individual contribution. To guarantee this recognition, each man's progress is reviewed every 6 months. SALARY — C.A.L. recognizes its need for above average professionals, and appreciates that such individuals must be compensated accordingly. Annual salary for an Associate Engineer (median of the five non-supervisory categories) can exceed $10,000. INTERNAL RESEARCH — each year the Laboratory sets aside substantial sums for the sole use of staff members in support of their exploration of new scientific areas and the generation of new ideas.

Action to take: If you desire additional information, use the coupon to request "A Decade of Research," a 68 page report on the Laboratory's research programs over the past 10 years. If you are interested in employment at C.A.L., check the box below for additional information. All inquiries will be treated as confidential.

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815. Aeronautical Engineer—Desires position in the development of research and engineering subject classifications for airplane and guided-missile information and in other phases of documentation of technical reports, or a position in technical editing and translation. Sixteen years' experience with the Navy Department in organizing and maintaining a bibliographic research office; setting up a system of subject classification, abstracting, and reference service, and in training personnel in these procedures. Author of *Subject Classification of Technical Reports* and other books for the Navy, and editor of *The Technical Data Digest* for the USAF.

814. Flight Test Engineer—BAE. Desires responsible position to capitalize on 11 years' experience in planning, directing, and writing reports on flight tests of naval, research, and transport aircraft. Background applicable to sales, liaison, and administrative engineering. Age 31.

813. Project Manager—B.S. in C.E., University of Illinois. Nineteen years' diversified aircraft experience at responsible levels including production planning, cost estimating, engineering design, and master planning. Extensive technical background coupled with proved supervisory and administrative ability. Currently in charge of major engineering and manufacturing program. Prefer West Coast location. Present earning $15,000 per annum. Résumé sent upon request to those who send particulars in first letter.

811. Representative-Mfg. Agent-Executive—Desires association with Government products division of commercial equipment firm. Represent at Dayton, Ohio, or Southwest preferred. B.A. and M.B.A. degrees (Industrial Management). Twenty years' experience in sales, service, and production—Government and industry. Buyer aircraft equipment (Air Force), Wright Field, Ohio. Also field representative and automotive staff experience. Brochure available.

Change of Address

Since the Post Office Department does not as a rule forward magazines to forwarding addresses, it is important that the Institute be notified of changes in address 30 days in advance of publishing date to ensure receipt of every issue of the *Journal* and *Review*.

Notices should be sent directly to the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

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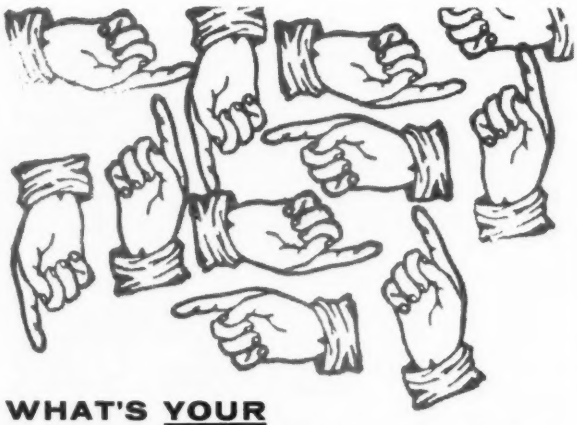

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Reduced weight and higher strength are now casting realities. Thinner sections, lighter parts are now possible. Castings can be stressed to new limits. Alcoa's new high-strength process guarantees you high properties.

Formerly, the properties of a casting were based on separately cast test bars. In design and application, a casting factor had to be applied to reduce these properties. With Alcoa's new high-strength casting method, properties are based on bars cut right from the casting itself. No reducing necessary. And, best of all, the guaranteed properties are in *all* the castings in the run . . . consistent, guaranteed, high properties in castings for aircraft structural parts.

New carefully controlled foundry practice and improved alloys are the developments responsible. The alloys are A356 and C355. These are the same composition and meet specifications for familiar alloys 356 and 355, with one difference: Impurities are controlled to a new minimum. Iron content, for example, is held to 0.2% in the improved alloys. Such seemingly minor changes make a whale of a difference.

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High-strength castings can be made in sand or plaster molds . . . sometimes in permanent molds. Alcoa's standard guarantee of properties for alloy A356-T61 is 38,000 psi tensile, 28,000 psi yield, and 5% elongation. Occasionally, because of complex shapes and designs, high strength can be furnished only in certain areas of the casting. But, by working closely with the designer, Alcoa can usually put the high strength right where it's needed.

Your Alcoa sales engineer has the facts on this new process. Let him work with you in obtaining castings with high properties—properties that don't have to be reduced in application. Aluminum Company of America, 1801-J Alcoa Building, Pittsburgh 19, Pennsylvania.

Important missile structural castings for Douglas. Alcoa's high-strength casting process and alloy A356-T61 give them some of the highest properties ever cast. Here are the properties obtained on test bars cut from the castings.

	Tensile, ksi	*Yield, ksi*	*Elongation, %*
Front Casting			
Average	43.2	32.1	9.7
Maximum	44.4	34.1	11.0
Minimum	40.5	30.3	6.7
Tests—8 from 8 production runs			
Back Casting			
Average	43.1	34.3	5.5
Maximum	47.1	36.9	9.0
Minimum	40.2	32.2	4.0
Tests—22 from 12 production runs			
Minimum Required	**40.0**	**30.0**	**3.0**

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ROSTER

of

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1957–1958

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Manager of Member Services

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National Headquarters

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New York 21, N.Y.

Western Headquarters and Pacific Aeronautical Library

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Los Angeles 36, Calif.

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THE INSTITUTE OF THE AERONAUTICAL SCIENCES

ITS PURPOSE

The Institute of the Aeronautical Sciences, established in 1932, is the representative society in America for professional engineers and specialists in all the sciences related to aeronautics. Its individual members form the nucleus of practically every aircraft and missile design and development project in the United States and abroad.

The basic mission of the Institute is to facilitate the exchange and evaluation of technical ideas among all engineers engaged in aeronautical work, wherever they may be. This is accomplished in two ways. First, the IAS maintains a carefully planned program of technical meetings, symposiums, and field trips to important aeronautical installations. Held on local, national, and international scales, IAS meetings provide an open forum for the testing and evaluation of new theories, new ideas, and new developments in every technical and scientific phase of aeronautics. Secondly, these meetings are supplemented by the official publications of the Institute, which serve to disseminate the results of new research and theory to engineering and scientific staffs in all parts of the world.

The Institute also maintains one of the finest research libraries on aeronautics in existence today. These facilities provide ready access to a source of technical information and specialized services of inestimable value to the aeronautical profession and the industry.

Through such active interchange of information, the Institute services the technical needs of one of the world's most exacting professional groups. Its only objective is the advancement of the arts and sciences of aeronautics.

IAS MEMBERSHIP

To be elected to membership in the Institute of the Aeronautical Sciences is an honor and privilege. Applicants are carefully graded upon the recommendations of members. They are then considered by a Membership Committee, and the new members are elected to those grades of membership to which their experience, qualifications, and contributions entitle them.

An important function of the Institute has been, from its beginning, to give recognition to achievement in aeronautics and to encourage outstanding work in its related technical fields. The Institute honors those who have "attained a position of distinction and made notable or valuable contributions in one of the aeronautical sciences or aeronautical engineering" by the annual presentation of Honorary Fellowship and Fellowship awards.

It also presents various awards and certificates of citation to those individual pilots, engineers, and scientists who make the most notable contributions to the advancement of aeronautics, aviation medicine, and aerology each year.

Since the Institute's membership is composed largely of those individuals and firms who have developed the aeronautical sciences to their present-day levels, the foremost privilege offered any member is the advantage of association, contact, and collaboration with such members in a mutuality of interests and purposes. Through national and local Section meetings, organized and supervised by the Institute, personal contacts and exchange of ideas are afforded to IAS members.

IAS MEETINGS

The Institute holds two general meetings annually, one in New York in January (4–5 days of Technical Sessions, plus the Honors Night Dinner) and one in Los Angeles in summer (4 days of Technical Sessions, plus field trips and a dinner). Other more specialized meetings are also scheduled. In 1956–1957 there were the following additional events:

(1) CAI-IAS Joint International Meeting, Toronto, Ont., Canada, November 26–27, 1956.
(2) Guided Missile Meeting and Inspection Trip, Holloman ADC and White Sands Proving Ground, N.M., November 19–20, 1956.
(3) Twentieth Wright Brothers Lecture, Washington, D.C., December 17, 1956.
(4) Twelfth Annual Flight Propulsion Meeting (with NACA), Cleveland, March 14–15, 1957.
(5) National Conference on Aeronautical Electronics, jointly with IRE, Dayton, Ohio, May 13–15, 1957.
(6) National Telemetering Conference, jointly with AIEE and ISA, El Paso, Tex., May 27–29, 1957.
(7) National Naval Aviation Meeting, San Diego, Calif., August 5–10, 1957.

In addition to the IAS National Meetings, the 28 local Sections held over 275 technical meetings during the year. During the same period, our 73 Student Branches held some 460 meetings.

IAS LIBRARY SERVICES

Since its inception, the IAS has recognized the value of a comprehensive, up-to-date library to the aeronautical engineer and scientist. Through the library, he has access to the vast body of aeronautical knowledge—the record of advances in the aeronautical sciences and the results of theoretical and experimental investigations.

The IAS Library in New York maintains an extensive collection spanning many years of aeronautical research and development. More than 8,000 technical books, 5,000 volumes of periodicals, and 50,000 reports are indexed and cataloged. An active acquisition program constantly brings in new publications from many countries, in many languages.

Through a liberal circulation policy, many thousands of reports and periodicals, as well as books, are loaned without charge by mail each year to Individual and Corporate Members. Photocopy facilities are available for those who need retention copies, and the Library's specialized reference tools provide access to literature on many subjects.

A competent staff of editors and abstracters scans all current publications for prompt abstracting in the International Aeronautical Abstracts, Aeronautical Reviews, and Books sections of the AERONAUTICAL ENGINEERING REVIEW. Annually, these sections are cumulated into the AERONAUTICAL ENGINEERING INDEX.

The Pacific Aeronautical Library in Los Angeles provides its subscribers with interlibrary loan and reference services. It also issues a periodical and report index, available at cost to subscribers.

IAS PUBLICATIONS

In addition to its monthly technical periodicals, the AERONAUTICAL ENGINEERING REVIEW and the JOURNAL OF THE AERONAUTICAL SCIENCES, the Institute publishes annually the AERONAUTICAL ENGINEERING CATALOG and the AERONAUTICAL ENGINEERING INDEX. It also publishes the Proceedings of special meetings.

The REVIEW contains aeronautical news; papers on applied engineering and aircraft production; and abstracts of articles, reports, and new books. It includes International Aeronautical Abstracts, a special up-to-the-minute section of abstracts of the world's litera ture, supported, in part, by a contract with the Air Force Office of Scientific Research of the ARDC. This monthly feature is now being translated into French and German for distribution through the European Office of ARDC throughout Western Europe. The JOURNAL publishes scientific papers on new research and developments in all fields applied to aeronautics. The CATALOG is a guide to the manufacturers of all aircraft and guided missile products.

Through the Sherman M. Fairchild Publication Fund, the IAS publishes specialized technical reports and selected preprints of papers presented at regular Institute meetings.

A number of publications designed to advance student interest and knowledge in the Aeronautical Sciences have been issued by the IAS under the auspices of the Minta Martin Aeronautical Student Fund and the Giannini Film Library Fund.

IAS BUILDINGS

The IAS National Headquarters on Fifth Avenue, New York, houses the IAS libraries and museum collections, together with a staff to handle the Institute's many services.

Western Headquarters in Los Angeles, coupled with the San Diego building, provide auditoriums, meeting rooms, libraries, and other conveniences desirable for the activities of any scientific society. The Technical Film Catalog (under the auspices of the ARDC) is housed in the San Diego facility.

New York

Los Angeles

San Diego

IAS HONORS AND AWARDS

Honorary Fellows

Honorary Fellows shall be persons of eminence in aeronautics and are elected by the Fellows and Honorary Fellows of the Institute residing in the United States. No more than one person residing in the United States, nor more than one person residing in a foreign country, may be elected as Honorary Fellow in any one year.

J. Ackeret
Joseph S. Ames (Deceased)
Henry H. Arnold (Deceased)
F. R. Banks
Preston R. Bassett
Frank W. Caldwell
Ralph S. Damon (Deceased)
Sir Geoffrey de Havilland
Walter S. Diehl
James H. Doolittle
Donald W. Douglas
Hugh L. Dryden
W. F. Durand
Sir Richard Fairey (Deceased)
Sir Wm. S. Farren
Sir Roy Fedden
Lester D. Gardner (Deceased)
Leroy R. Grumman
Harry F. Guggenheim
Sir Frederick Handley Page
J. C. Hunsaker
Sir B. Melvill Jones
J. H. Kindelberger
George W. Lewis (Deceased)
Glenn L. Martin (Deceased)
Peter G. Masefield
George J. Mead (Deceased)
Clark B. Millikan
J. H. Parkin
J. Laurence Pritchard
Sir David Pye
Arthur E. Raymond
Igor I. Sikorsky
Sir Richard V. Southwell
Sir Geoffrey Taylor
Sir Henry Tizard
Th. von Kármán
Charles C. Walker
Edward Warner
Orville Wright (Deceased)
T. P. Wright

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The Octave Chanute Award

This award was established by the Institute in 1939 to honor the memory of Octave Chanute, pioneer American aeronautical investigator, who died in 1910. It is presented annually for a notable contribution made by a pilot to the aeronautical sciences.

1939—Edmund T. Allen (Deceased)
1940—Howard Hughes
1941—Melvin N. Gough
1942—Albert Lewis MacClain
1943—William Henry McAvoy
1944—Colonel Benjamin S. Kelsey
1945—Robert T. Lamson and A. Elliott Merrill
1946—Ernest A. Cutrell
1947—Lawrence A. Clousing
1948—Herbert H. Hoover (Deceased)
1949—Captain Frederick M. Trapnell
1950—Commander Donald Bertram MacDiarmid
1951—Lieutenant Colonel Marion E. Carl
1952—John C. Seal
1953—William B. Bridgeman
1954—George E. Cooper
1955—Major General Albert Boyd
1956—A. M. Johnston
1957—Lt. Col. Frank K. Everest, Jr.

The John Jeffries Award

Honoring the memory of Dr. John Jeffries, an American physician who, with Blanchard, the French balloonist, made the first aerial voyage across the English Channel in 1785 and on a previous voyage made the earliest recorded scientific observation from the air, this award was established by the Institute in 1940 to give recognition to the importance to aviation of scientific endeavor in the field of medicine. It is presented annually for outstanding contributions to the advancement of aeronautics through medical research.

1940—Dr. Louis H. Bauer
1941—Major Harry G. Armstrong
1942—Dr. Edward C. Schneider
1943—Brigadier General Eugen G. Reinartz
1944—Air Marshal Sir Harold E. Wittingham
1945—Commodore John C. Adams
1946—Brigadier General Malcom C. Grow
1947—Dr. J. Winfred Tice
1948—Dr. W. Randolph Lovelace, II
1949—Dr. Arnold D. Tuttle (Deceased)
1950—Brigadier General Otis O. Benson, Jr.
1951—Captain John R. Poppen
1952—Lieutenant Colonel John P. Stapp
1953—Captain Charles F. Gell
1954—Dr. James P. Henry
1955—Captain Wilbur E. Kellum
1956—Ross A. McFarland

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The Robert M. Losey Award

Established in 1940, this award honors the memory of Capt. Robert Moffatt Losey, a member of the Institute and a meteorologic officer of the Air Corps, who was killed at Dombas, Norway, April 21, 1940, while serving as an official observer for the U.S. Army. He was the first officer in the service of the United States to die in World War II. It is presented annually in recognition of outstanding contributions to the science of meteorology as applied to aeronautics.

1940—Henry Garrett Houghton, Jr.
1941—Horace Robert Byers
1942—Francis Wylton Reichelderfer
1943—Lieutenant Colonel Joseph J. George
1944—John Cary Bellamy
1945—Major Harry Wexler
1946—Carl G. Rossby
1947—Colonel Benjamin G. Holzman
1948—Paul A. Humphrey
1949—William Lewis
1950—Roscoe R. Braham, Jr.
1951—Ivan R. Tannehill
1952—Vincent J. Schaefer
1953—Henry T. Harrison, Jr.
1954—Hermann B. Wobus
1955—Lieutenant Colonel Robert C. Bundgaard
1956—Ross Gunn

The Sylvanus Albert Reed Award

The late Dr. S. A. Reed, designer of metal aircraft propellers and a Founder Member of the Institute, made an endowment to the Institute in 1933 to provide an annual award to be presented for a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations which have had a beneficial influence on the development of practical aeronautics. The recipient of this award is chosen by ballot of the American Honorary Fellows and Fellows of the Institute.

1934—C. G. Rossby and H. C. Willett
1935—Frank W. Caldwell
1936—Edward Story Taylor
1937—Eastman Nixon Jacobs
1938—Alfred Victor de Forest (Deceased)
1939—George J. Mead (Deceased)
1940—Hugh L. Dryden
1941—Th. von Kármán
1942—Igor I. Sikorsky
1943—Sanford A. Moss (Deceased)
1944—Fred E. Weick
1945—Charles S. Draper
1946—Robert T. Jones
1947—Galen B. Schubauer and Harold K. Skramstad
1948—George W. Brady
1949—George S. Schairer
1950—Robert R. Gilruth
1951—E. H. Heinemann
1952—John Stack
1953—Ernest G. Stout
1954—Clark B. Millikan
1955—H. Julian Allen
1956—Clarence L. Johnson

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The Lawrence Sperry Award

This award was endowed in 1936 by the sister and brothers of the late Lawrence Sperry, pioneer aviator and inventor, who died in 1923 at the age of 31. It is presented annually for a notable contribution made by a young man to the advancement of aeronautics.

1936—William C. Rockefeller
1937—Clarence L. Johnson
1938—Russel C. Newhouse
1939—Charles M. Kearns, Jr.
1940—William B. Oswald
1941—Ernest G. Stout
1942—Edward C. Wells
1943—William B. Bergen
1944—William H. Phillips
1945—Richard Hutton
1946—Peter R. Murray
1947—Commander Noel A. M. Gayler
1948—Allen E. Puckett
1949—Alexander H. Flax
1950—Frank N. Piasecki
1951—Robert C. Seamans, Jr.
1952—Dean R. Chapman
1953—Donald Coles
1954—A. Scott Crossfield
1955—Giles J. Strickroth
1956—George F. Jude

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Wright Brothers Lecture

The Wright Brothers Lecture is presented annually on December 17, the anniversary of the first airplane flight made by the Wright Brothers. It is endowed by the Vernon Lynch Fund and was established in 1937. The Lecturers are distinguished aeronautical scientists from this country and abroad.

B. Melvill Jones	Flight Experiments on the Boundary Layer
Hugh L. Dryden	Turbulence and the Boundary Layer
Clark B. Millikan	The Influence of Running Propellers on Airplane Characteristics
Sverre Pettersen	Recent Fog Investigations
Richard V. Southwell	New Pathways in Aeronautical Theory
Edmund T. Allen	Flight Testing for Performance and Stability
W. S. Farren	Research for Aeronautics—Its Planning and Application
John Stack	Compressible Flows in Aeronautics
H. Roxbee Cox	British Aircraft Gas Turbines
Th. von Kármán	Supersonic Aerodynamics—Principles and Applications
Sydney S. Goldstein	Low Drag and Suction Airfoils
Abe Silverstein	Research on Aircraft Propulsion Systems
A. E. Russell	Some Factors Affecting Large Transport Aeroplanes with Turboprop Engines
William Bollay	Aerodynamic Stability and Automatic Control
P. B. Walker	The Experimental Approach to Aircraft Structural Research
William Littlewood	Technical Trends in Air Transport
Glenn L. Martin (Deceased)	The First Half-Century of Flight in America
Bo Lundberg	The Fatigue Life of Airplane Structures
R. L. Bisplinghoff	Some Structural and Aeroelastic Considerations of High-Speed Flight
Sir Arnold Hall	Some Comments on Current Aviation Topics

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Minta Martin National Awards

This award is presented annually for the best technical papers given at IAS Regional Student Competitions.

1955—David L. Cochran, Graduate Division
Voight R. Hodgson, Undergraduate Division
1956—Ely S. Levinsky, Graduate Division
Richard F. Weick, Undergraduate Division

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Water-Based Aviation Award

This award honors the memory of Edwin C. Musick, pioneer of overseas air transport routes, who was killed on January 12, 1938, while in command of the first commercial flight from the United States to New Zealand for Pan American World Airways. It is presented annually for meritorious work in the design or operation of water-based aircraft leading to advances in performance or utility. It was established in 1956.

The details of this new award were first announced at the IAS Honors Night Dinner on January 28, 1957. Coincidentally with this announcement, twelve of this nation's leading figures were cited for their contributions as pioneers in water-based aviation: Capt. Walter S. Diehl, USN (Ret.); C. L. Egtvedt; Jerome C. Hunsaker; J. H. Kindelberger; B. V. Korvin-Kroukovsky; I. M. Laddon; Grover Loening; C. J. McCarthy; Capt. H. C. Richardson, USN (Ret.); Capt. C. H. Schildhauer, USNR (Ret.); I. I. Sikorsky; and C. A. Van Dusen.

1957—John B. Parkinson

IAS MEMBERSHIP REQUIREMENTS

Excerpts from By-Laws

Article I—Membership

SECTION 1. All persons professionally engaged in the practice of the aeronautical sciences or in other work which contributes to the advancement of the aeronautical sciences shall be eligible in one of the grades of membership of the Institute. Consideration in grading is given to professional education and experience, publications, academic position, membership in other scientific and engineering societies, record of aeronautical designs created and contributions to scientific knowledge. A Bachelor's Degree in science or engineering shall be considered the equivalent of four years of aeronautical experience. All applicants must sign, before admission, an agreement that they will conform to the Constitution, By-Laws, and Rules of the Institute.

SECTION 5. A Fellow shall have been an Associate Fellow for one year or more and have attained a position of distinction in aeronautics. He shall have made notable and valuable contributions in one of the aeronautical sciences or in aeronautical engineering. Not more than ten Fellows residing in the United States and ten Fellows residing in foreign countries may be elected each year by vote of the Honorary Fellows and Fellows by secret mail ballot under rules prescribed by the Council. Fellows shall be proposed and elected by the Honorary Fellows and Fellows of the Institute residing in the United States. A favorable vote of three-fourths of those voting shall be required for election.

SECTION 6. An Associate Fellow shall have been engaged for not less than twelve years in the practice of the aeronautical sciences; and shall have been in responsible charge of important scientific or engineering work in aeronautics, or shall have done original work of outstanding character, or shall have otherwise made outstanding contributions to the aeronautical sciences. Applicants for this grade shall be recommended by not less than four members of the Institute of whom two or more shall be Fellows or Associate Fellows.

SECTION 7. MEMBERS shall be persons who have been engaged in professional work for at least eight years and have acquired a recognized standing in engineering, design, research, instruction, test flying, the application of the aeronautical sciences, or the technical development of the manufacture or operation of aircraft, aircraft power plants or other essential components or accessories of aircraft. To qualify for this grade applicants shall be recommended by not less than four persons of whom not less than two shall be members of the Institute.

SECTION 8. Associates shall be persons engaged in the application or development of aeronautics in administrative or other positions and who have acquired a recognized standing in aeronautics; or former Student Members who have been graduated and others engaged in scientific or engineering work in aeronautics or fields closely related to aeronautics. Applicants for this grade shall be recommended by not less than four persons of whom not less than two shall be members of the Institute.

SECTION 11. Student Members shall be undergraduate or graduate students attending those universities or schools where branches of the Institute have been organized. Student Members shall comply with, and be subject to, the Rules for Student Membership adopted by the Council.

SECTION 14. Honorary Fellows, Fellows, Honorary Members, Associate Fellows and MEMBERS shall be entitled to vote at meetings of the Institute, if in good standing. Proxies authorizing a voting member to vote for an absent member shall be signed by such absent member and shall be submitted to the Secretary in advance of the meeting for verification of the member's right to vote.

Article II—Dues

SECTION 1. An entrance fee of $10.00 shall be payable on election to the grades of Associate, MEMBER or Associate Fellow, except that no entrance fee shall be payable by an applicant residing permanently outside the United States and Canada or by a Student Member applying, within the prescribed time limit, for admission as an Associate.

SECTION 2. The annual dues shall be:

Fellows	$15.00
Associate Fellows	$15.00
MEMBERS	$15.00
Associates over age 28	$15.00
Associates under age 28	$ 7.00
Student Members	None

Dues shall include, except for Student Members, subscription to the AERONAUTICAL ENGINEERING REVIEW. Student Members may subscribe for the REVIEW at one-half the regular subscription rate. All members of the Institute residing in the United States and Canada may subscribe for the JOURNAL OF THE AERONAUTICAL SCIENCES at a special rate set by the Council.

For members residing permanently outside the United States and Canada annual dues shall be $10.00 in all grades and shall include subscription to the AERONAUTICAL ENGINEERING REVIEW and the JOURNAL OF THE AERONAUTICAL SCIENCES.

Beginning on the first of October next following his 28th birthday dues of an Associate shall be the same as those of all other elective grades.

A reinstatement fee of $10.00 shall be payable upon reinstatement of former members who had been dropped for nonpayment of dues.

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This Is Your Membership Emblem

Grades are identified by color scheme as follows:

Grade	*Field*	*Airfoil*
HF and F	Gold	Black
AF	Black	Gold
M	Silver	Black
A	Black	Silver
Student	White	Silver

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B

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C

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E

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G

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H

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R

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T

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U

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Linde Company, New York, N.Y.
National Carbon Company, New York, N.Y.
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Maintenance Base: South San Francisco, Calif.
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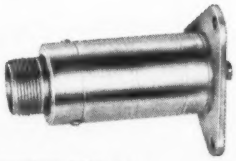
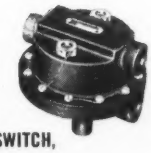


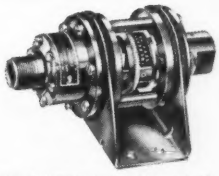
High Temperature (650° F.) PRESSURE SWITCH, Type 6576

CONSTRUCTION: All-welded stainless steel. Precision stacked-capsule sensing element. **TEMPERATURE RANGE:** —65° F. to 650° F. **ADJUSTMENT RANGE:** 20 to 75 psia. **RESET VALUE:** 2 psi. **CONTACTS:** 1 amp inductive snap action. **DIMENSIONS:** Diameter 1¼"; length 3½".



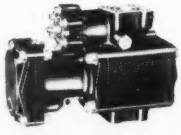
Differential PRESSURE SWITCH, Type 6580

DIFFERENTIAL ADJUSTMENT RANGE: 4" to 125" of water. **SYSTEM PRESSURES:** up to 60 psi. **RESET VALUE:** 1" to 3" of water (proportional to operating point). **EXTERNAL ADJUSTMENTS:** Separate adjustment of operating point and reset value. Alternate style provides two adjustable operating points with fixed reset values.



PRESSURE SWITCH (High Vibration), Type 6885

Integral vibration isolation. External adjustment doubly locked. Small physical size. Airframe, missile, rocket applications. **OPERATING RANGES:** 1 to 800 psi. **SYSTEM PRESSURES:** 5 to 3,000 psi. Available in single and dual assemblies, and in absolute pressure sensing model.

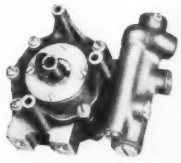


After Burner Fuel Control, Type 141RL37

Schedules afterburner fuel flow as a function of compressor discharge pressure absolute. Unique dual poppet design maintains constant pressure drop across the metering poppet; makes fuel flow a linear function of metering poppet lift. External adjustments permit slope and zero-shift alterations of flow versus compressor discharge pressure curve. **RATED FLOW:** 3,500 to 35,000 lbs/hr.

Dual Hydraulic Pressure Gauge, Type 6966

Dual hydraulic pressure indication within envelope normally occupied by single indicator. **DIAL SIZE:** 1⅞". Instant recognition of system condition—pointers horizontal denote full pressure. No translation. No reading of figures. Safety blow-out disc behind panel.



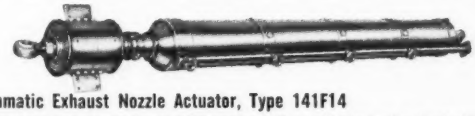
Rotary Torque Booster, Type 141F12

Controls fuel or hydraulic pressure to apply high level output force in response to low level input force. May be inserted in mechanical control linkage to reduce pilot effort. 8 to 1 torque amplification. Simple mechanical design. Poppet operated—not sensitive to dirt clogging. Output shaft will accept 1½° misalignment. Inherently stable.

"VAPOFLASH" Temperature Measuring Probe

A high temperature measuring element intended primarily for gas turbine applications. Provides proportional pneumatic output for 100° F. change in gas temperature. Connection of several units in parallel for averaging permits control of exhaust gas temperatures by variation of exhaust nozzle area, afterburner fuel flow, main engine fuel flow, or other dependent variable. **OPERATING RANGES:** 1,000° to 1,500° F.

Alternate style (Vapoflash Thermal Switch) provides actuation of electrical contacts within the range of 1,000° to 1,500° F.



Pneumatic Exhaust Nozzle Actuator, Type 141F14

Actuators are spaced equally around the tail pipe of a turbojet engine. Use compressor discharge pressure directly to position the exhaust nozzle. Actuator tandem four-piston design provides very high forces within small cross-sectional area. Synchonizing valves act to equalize position of driving points around exhaust nozzle. **EACH ACTUATOR:** 5,000 lbs. force with air at 200 psi. **INLET AIR TEMPERATURE:** 935° F. max. **BORE:** 3". **BARREL LENGTH:** 31.5". **MATERIALS:** Stainless steel, bronze.

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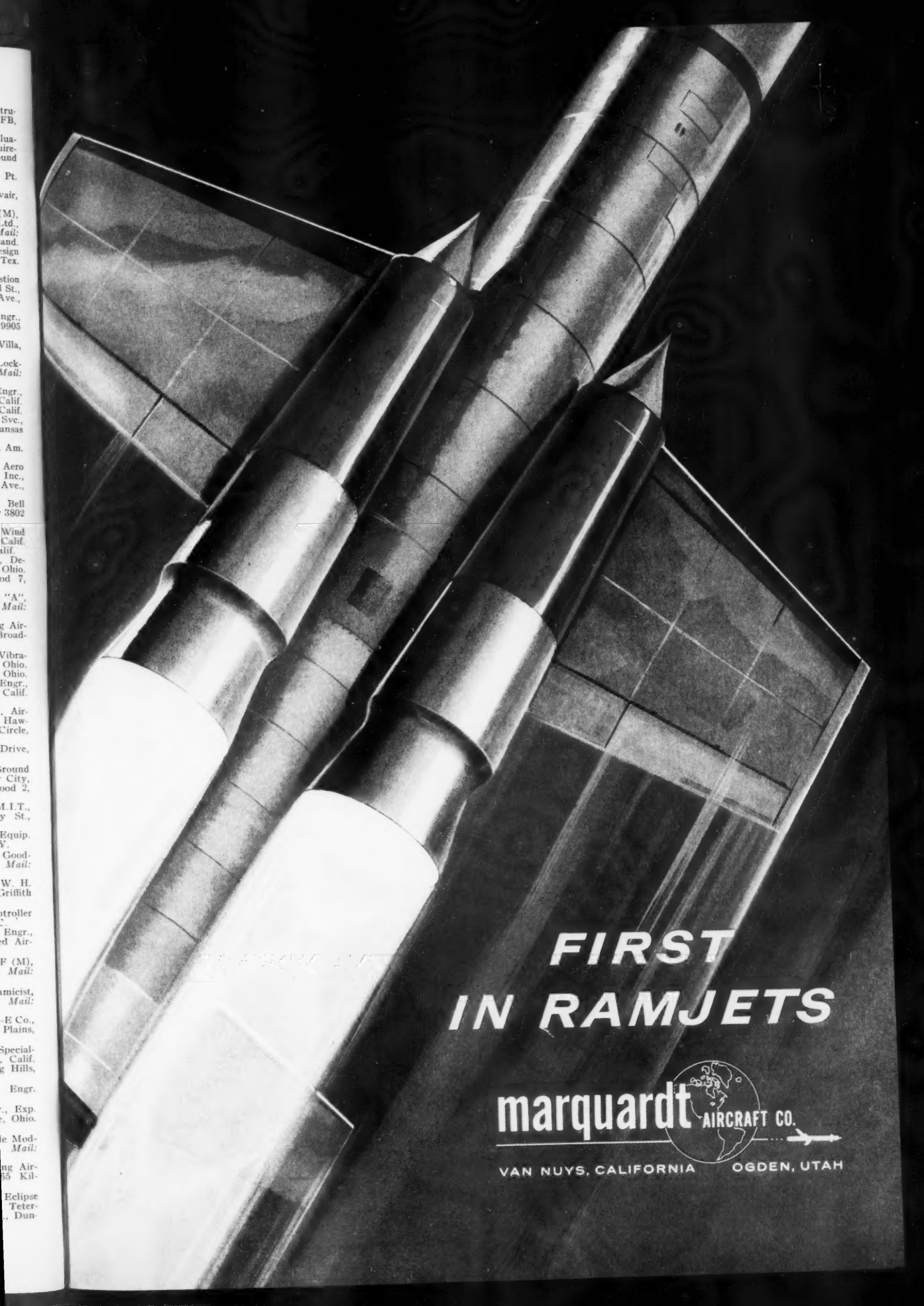
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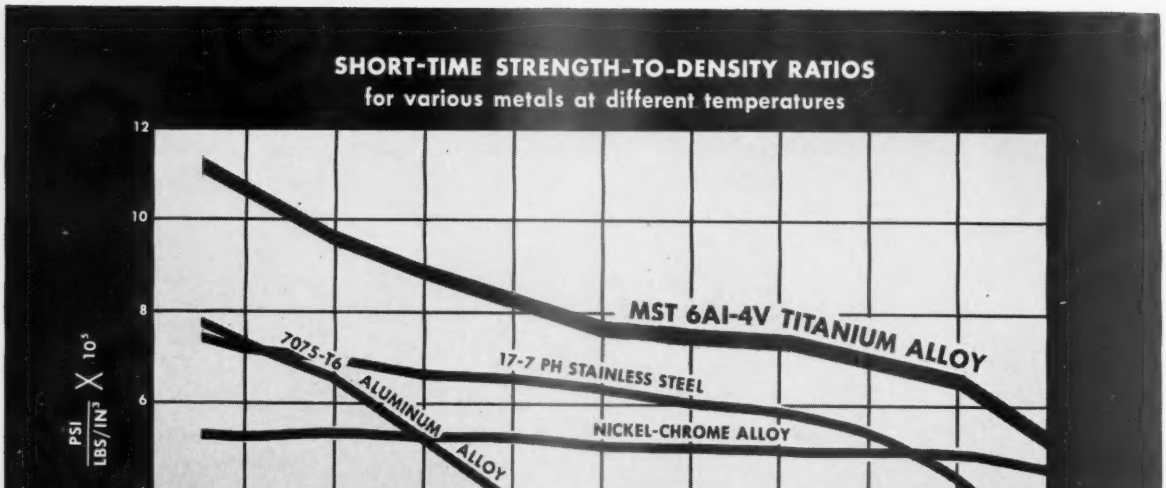

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Write Dept. D10 for copy of "Titanium Alloy Properties"

SELECTION GUIDE TO MST ALLOYS

Typical Mechanical Properties of Annealed Titanium and its Alloys

	Form	Ultimate Tensile Strength, psi	Yield Strength, psi	Elongation % *
COMMERCIALLY PURE TITANIUM				
MST Grade III	Sheet, Bar	70,000	50,000	25
(3 different strength levels)	Sheet, Bar	85,000	65,000	23
	Sheet, Bar	100,000	80,000	20
TITANIUM ALLOYS				
MST 6Al-4V				
Annealed	Bar	140,000	130,000	15
Age hardened (1)	Bar	165,000	155,000	12
Age hardened (2)	Bar	180,000	165,000	10
Annealed	Sheet	140,000	125,000	12
MST 3Al-5Cr	Bar	155,000	145,000	13
MST 4Al-4Mn	Bar	150,000	140,000	14
MST 8 Mn	Sheet	137,000	125,000	16

(1) 1650°F—1 hour—WQ; 1100°F—2 hours—AC
(2) 1700°F—1 hour—WQ; 1000°F—8 hours—AC

WQ—Water Quench
AC—Air Cool

* Values for 1" on bar and 2" on sheet

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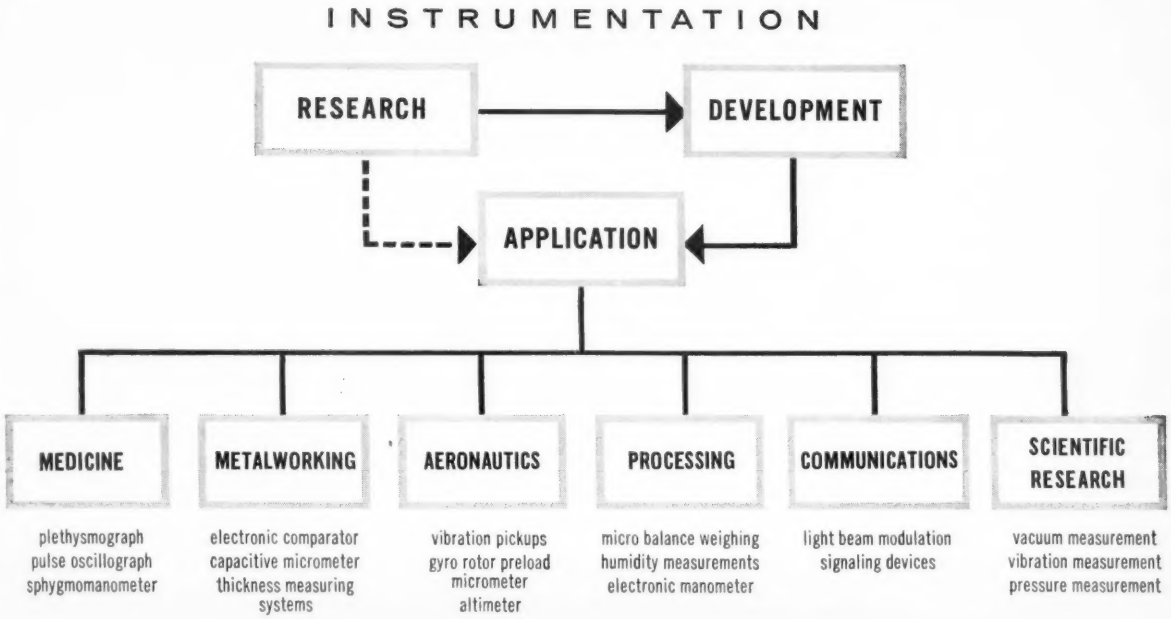

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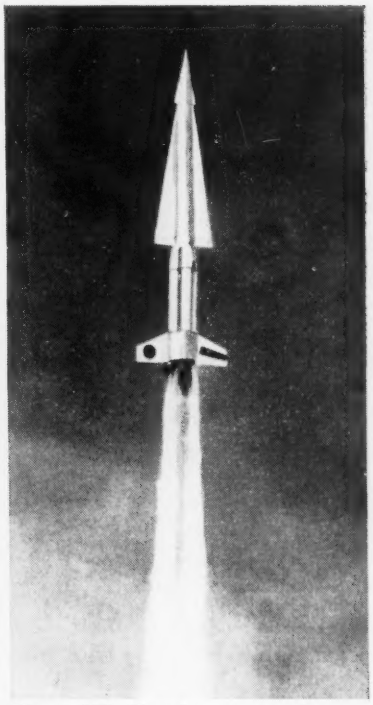

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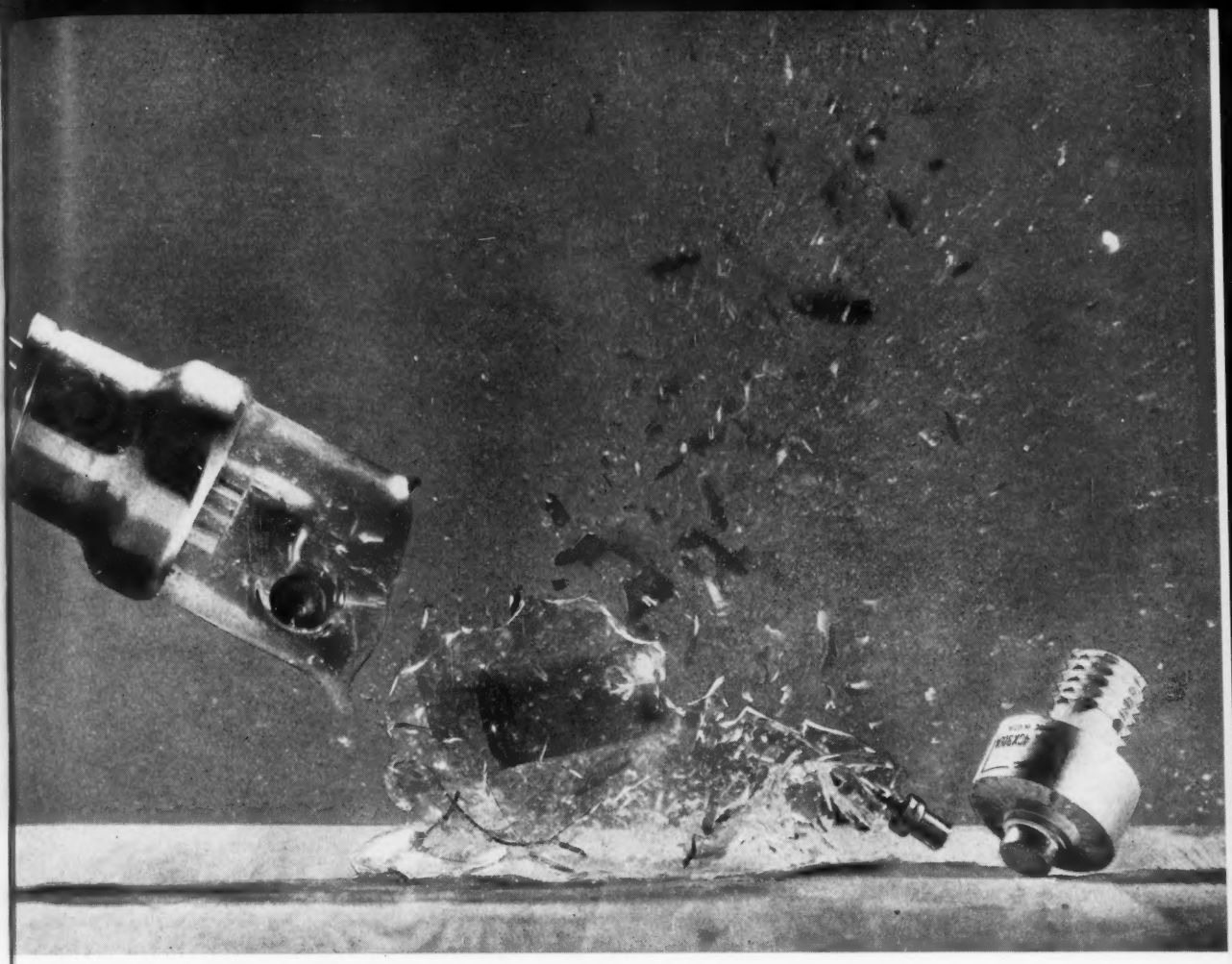

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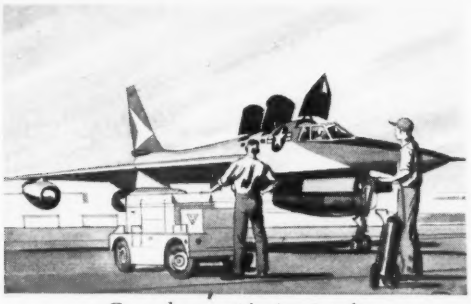

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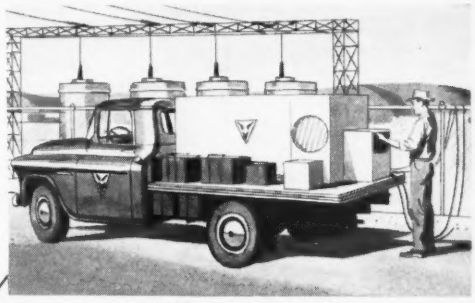

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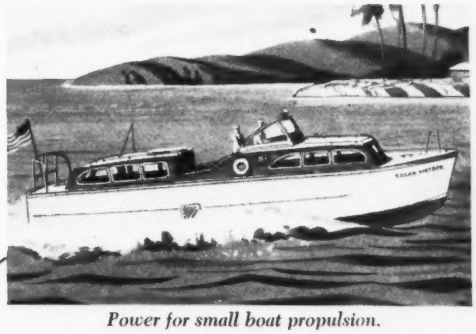

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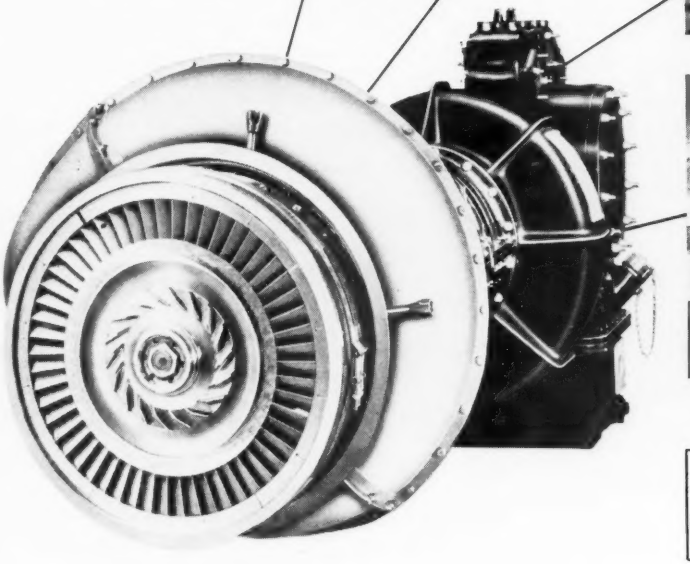

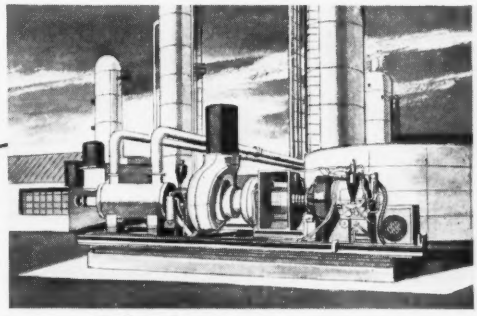

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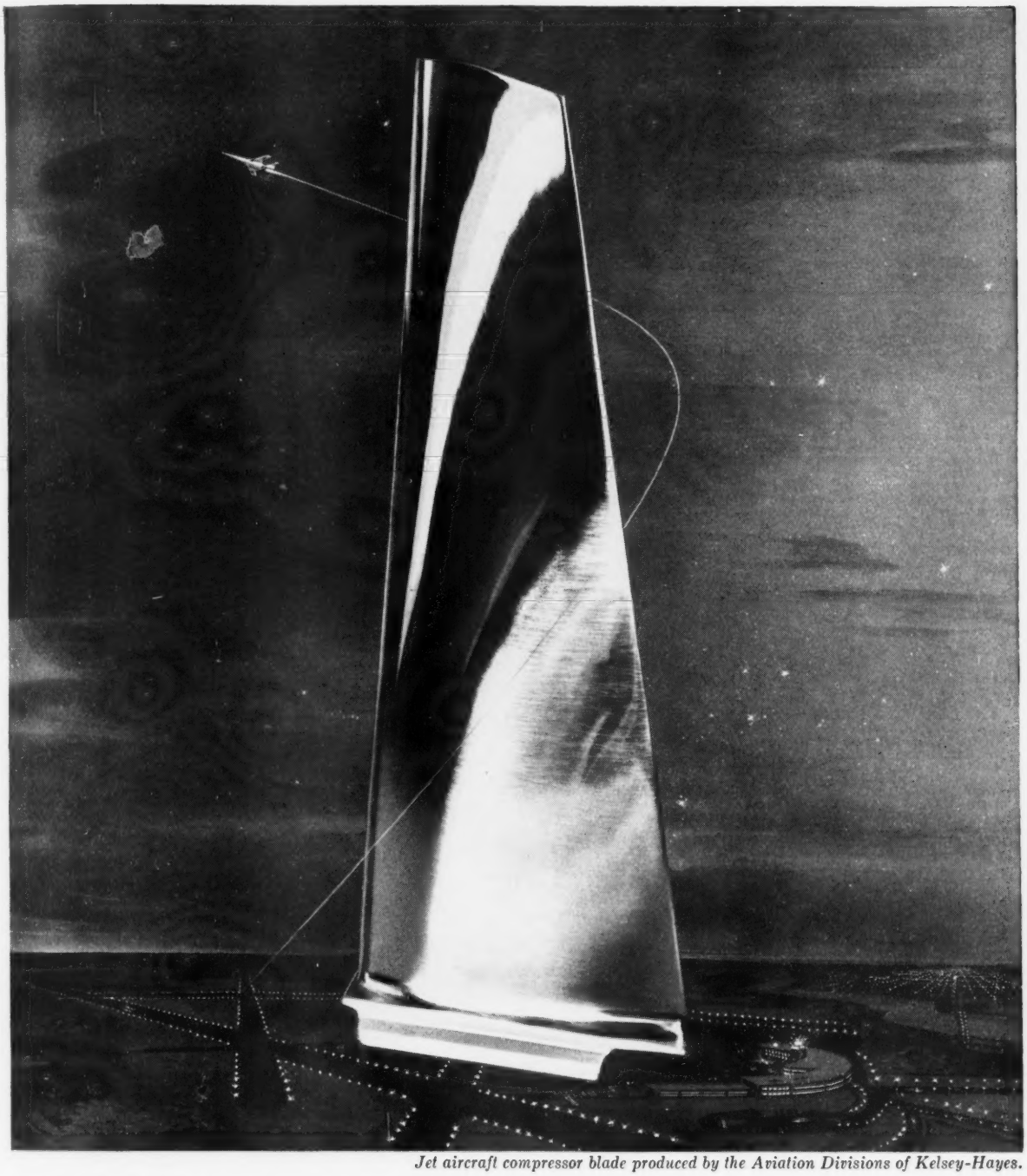

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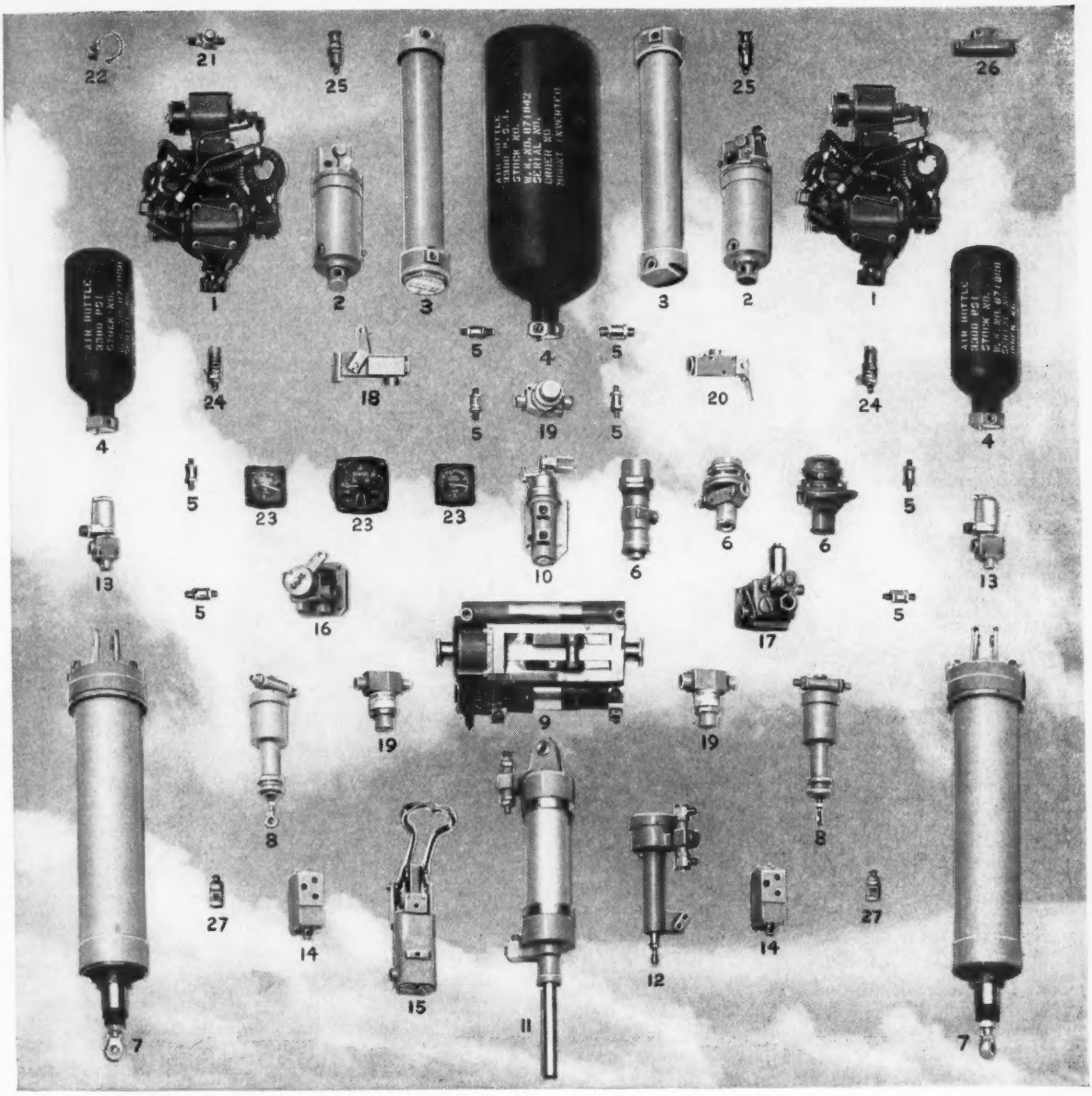

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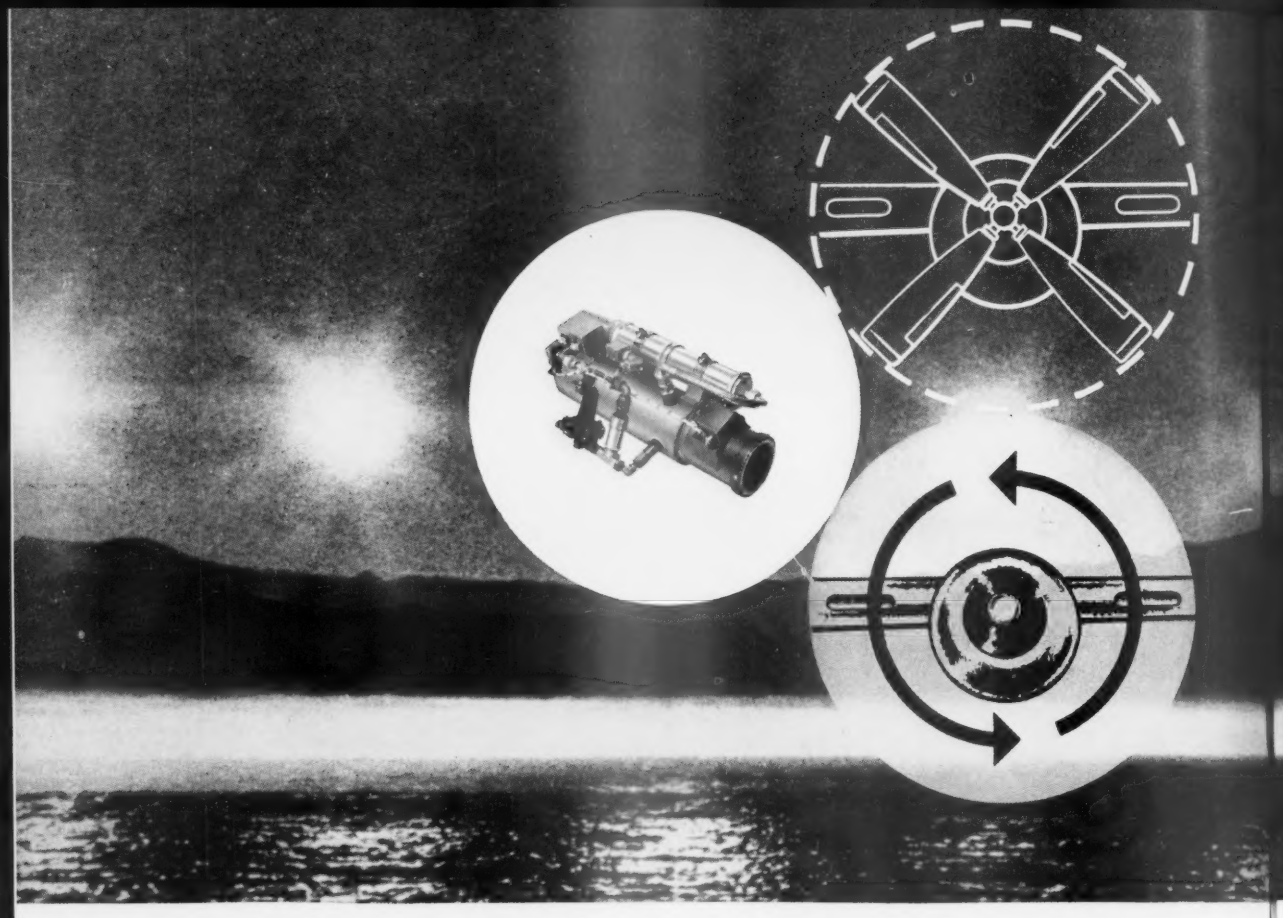

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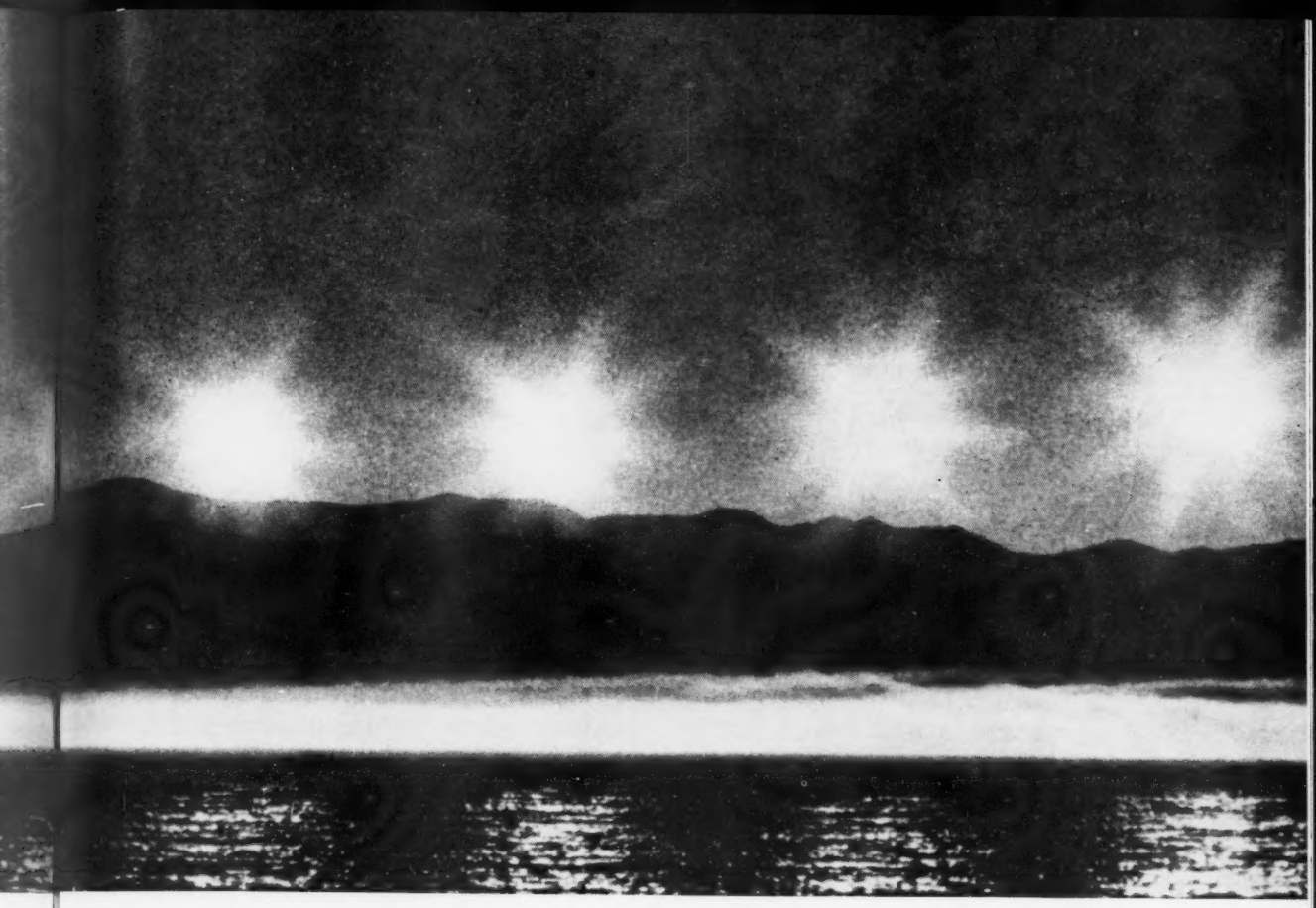

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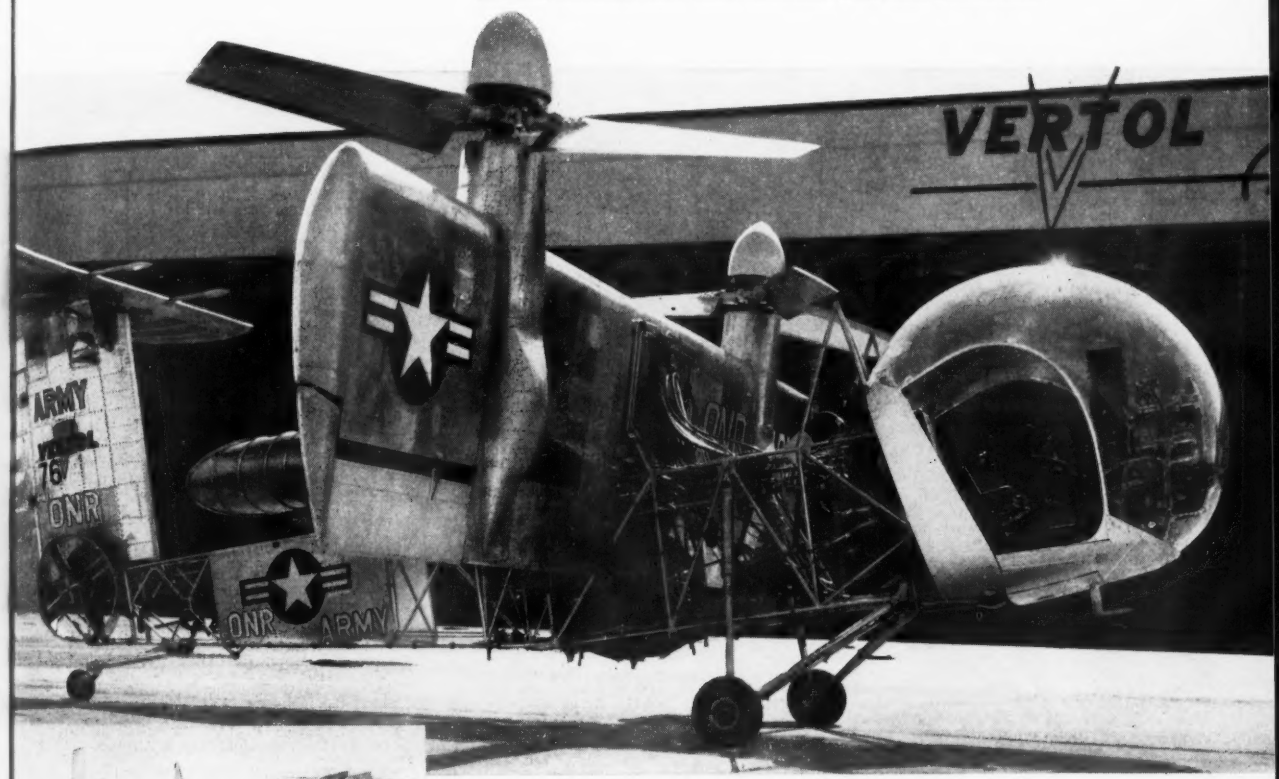

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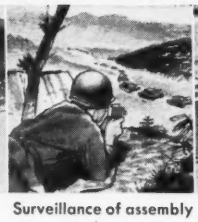

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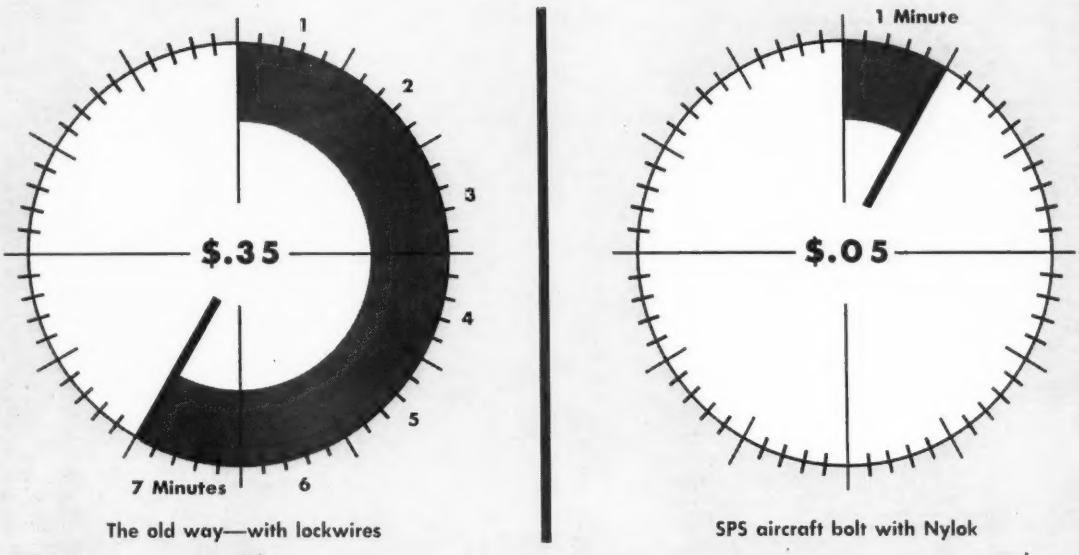
Average assembly time and labor cost—wired bolt vs.
SPS aircraft bolt with built-in Nylok locking element



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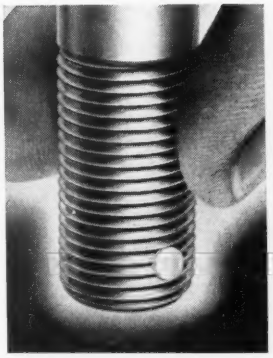

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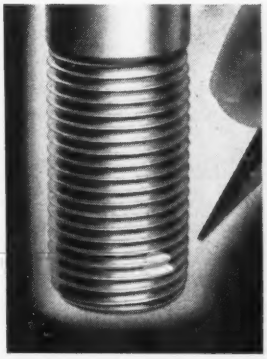

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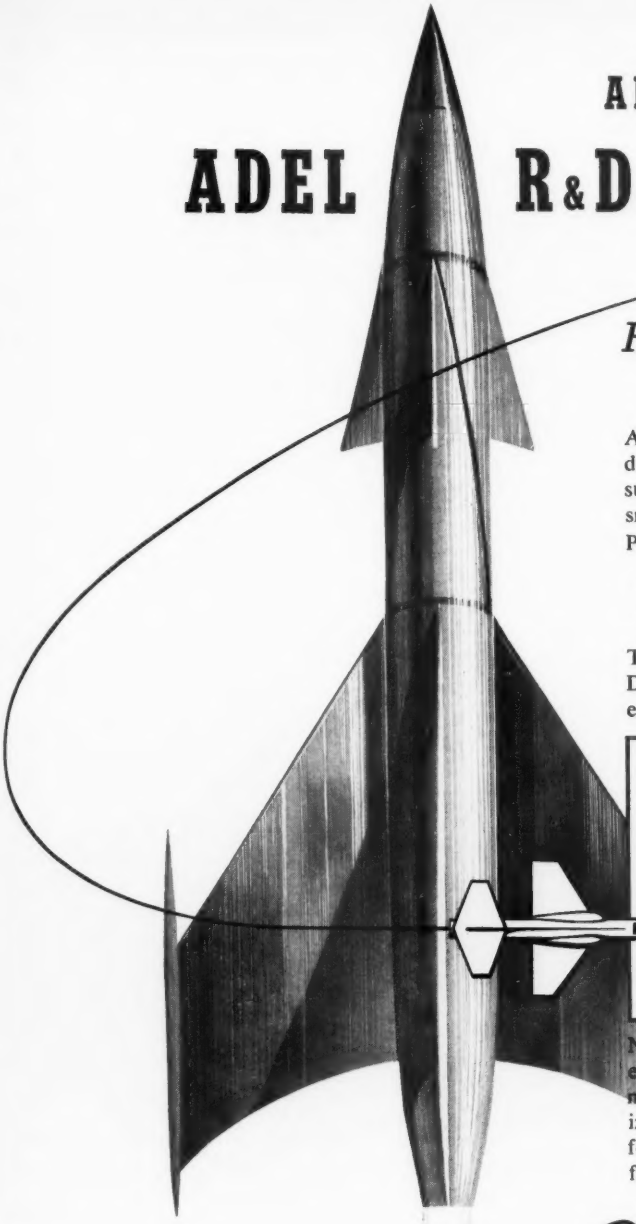

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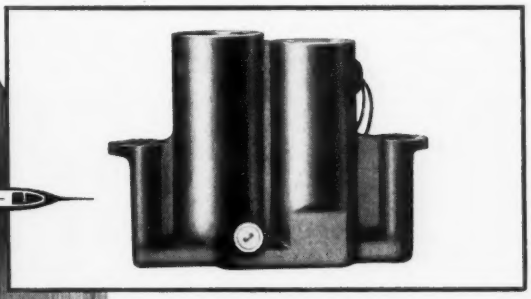

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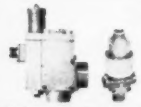

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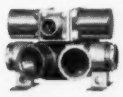

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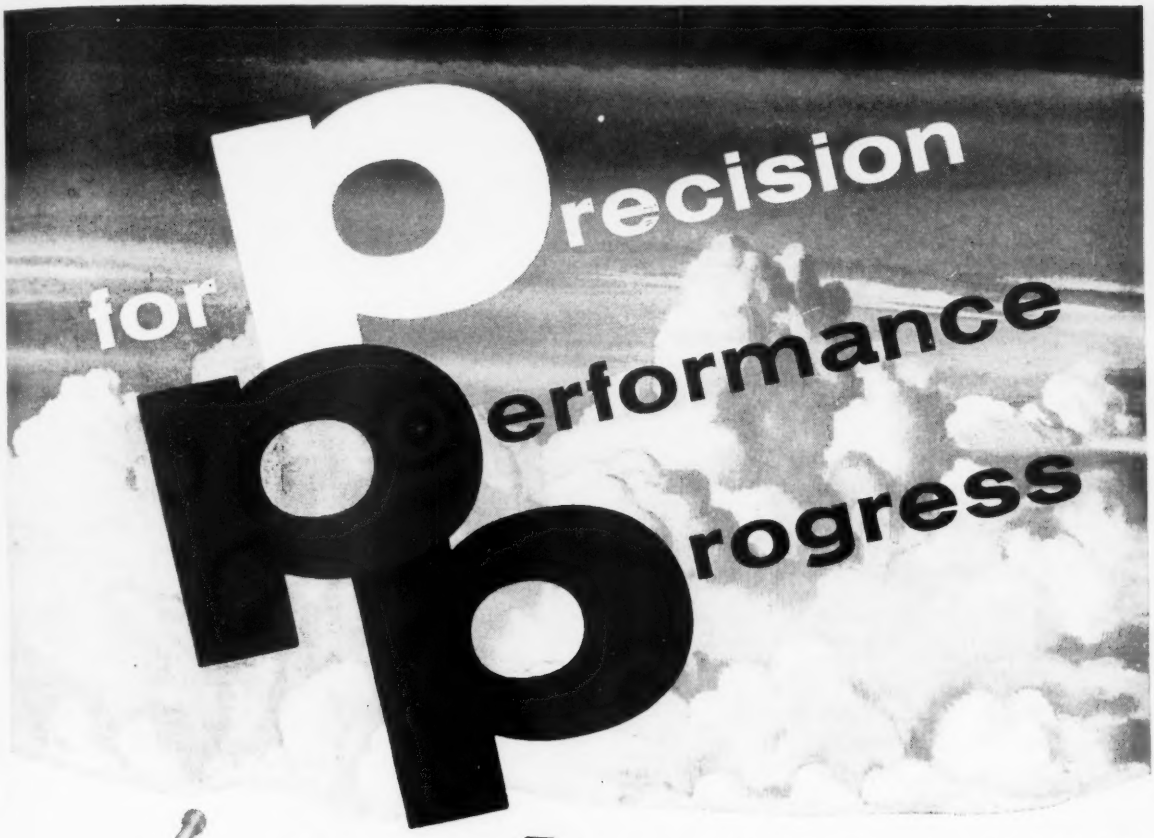

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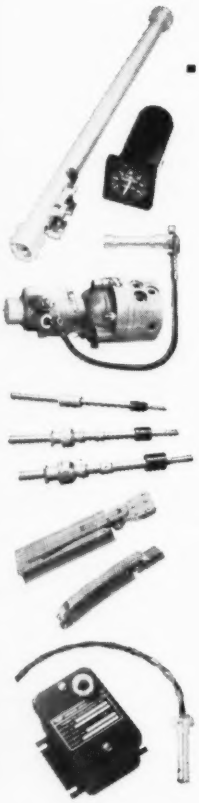

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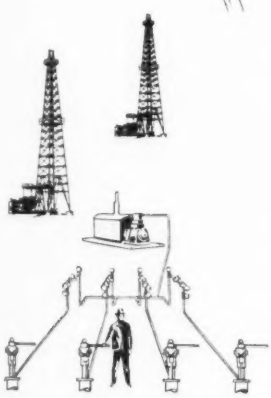

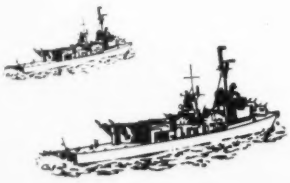

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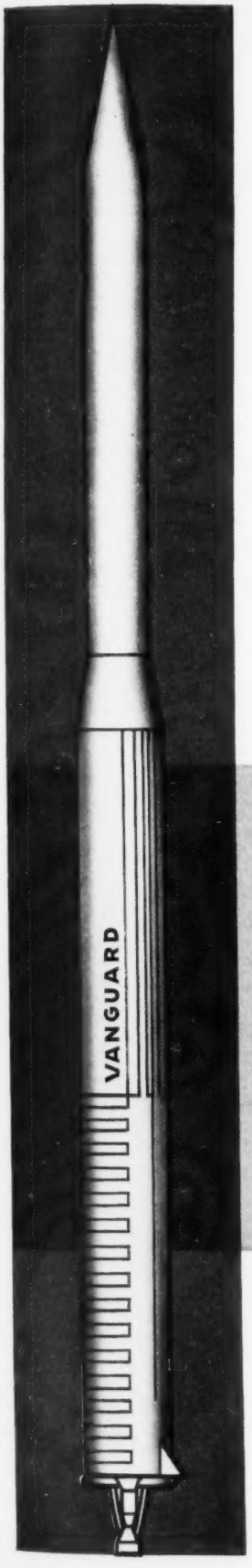

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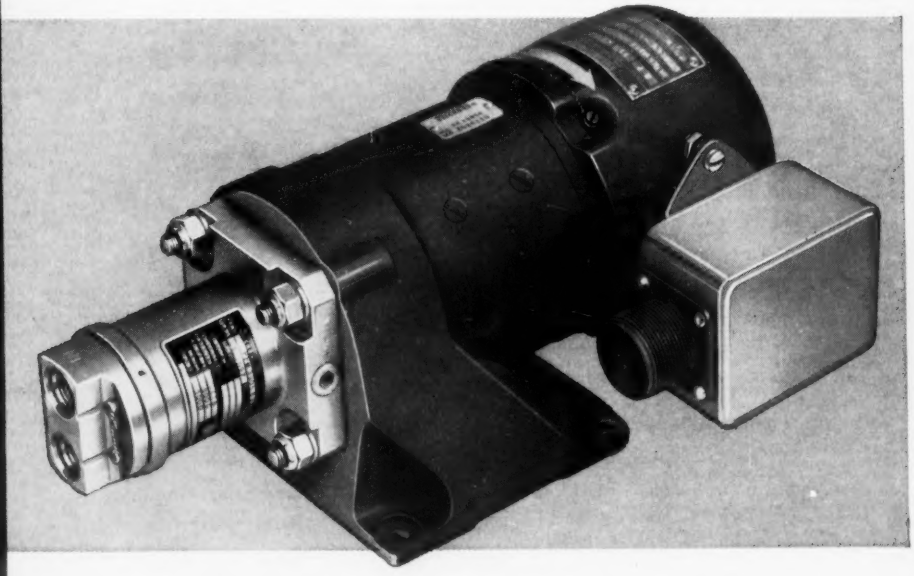

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Detzler, Stephen, Devel. Engr.
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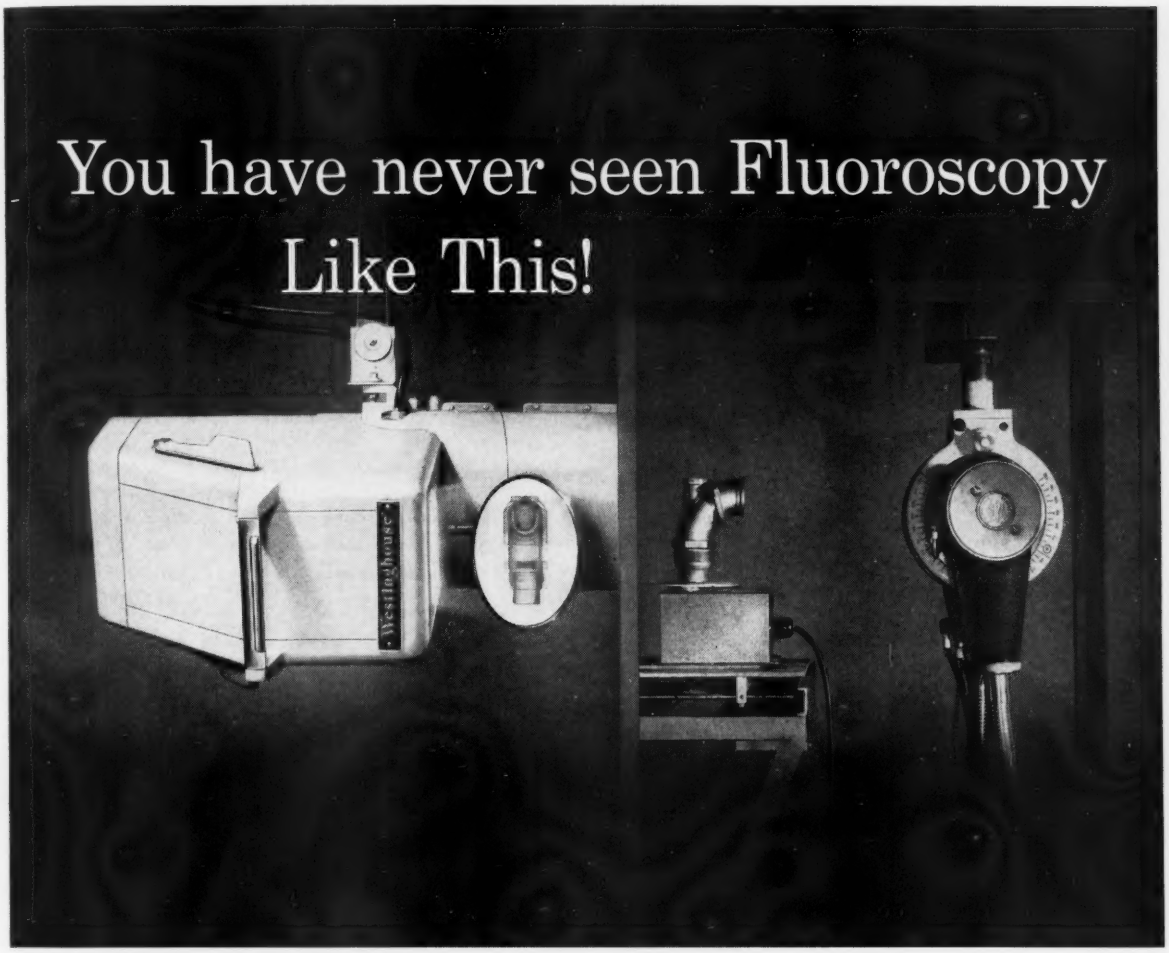

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Here's Use

HELI-COIL
Stainless Steel
Screw-THREAD Insert

This is the insert that permanently protects threads against wear, stripping, corrosion, galling, seizing, vibration and shock. Made of (18-8) stainless steel wire, cold-rolled into a diamond shaped cross-section, this ***Heli-Coil*** Insert is work hardened to a tensile strength of approximately 200,000 psi . . . conforms to military standards MS 122076 through 122275 (ASG) and MS 124651 through 124850 (ASG) . . . conforms to standard commercial and industrial thread forms, including coarse, fine, pipe-thread and MM sizes . . . permits use of standard boss configurations.

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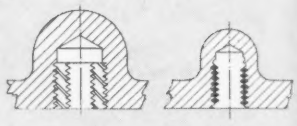

Save Space, Weight and Costs
Substantial savings in materials, weight, space and costs are possible, as against solid bushings, because smaller (or standard) bosses, flanges and threaded fasteners can be used.

New
HELI-COIL
Stainless Steel
Screw-LOCK Insert
Pat. Pending.

Conforming to military specifications for locking torque and vibration, this notable new ***Heli-Coil*** Screw-LOCK *one-piece* insert provides all the thread protection of the Screw-THREAD Insert, **PLUS** an exclusive internal locking feature that eliminates the need for clumsy protruding lock nuts, lock wiring and other supplementary locking devices . . . saves cost, space and weight . . . permits simplified streamlined design. The Insert is a permanently integrated part of the component—permits repeated service repair disassembly and reassembly, *with locking action remaining unimpaired.* Available in sizes from 4-40 up.

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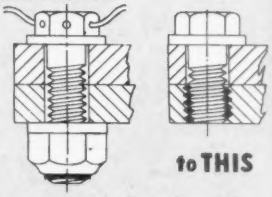
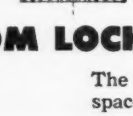


to THIS

Internal Locking Feature
Insures positive internal locking action—eliminates lock nuts, lock wiring and other protruding locking devices—saves space, weight, cost. Yet screw may be easily disassembled with no loss of locking torque.

➡ ***Heli-Coil*** **Field Engineers are at your service for**



CUSTOM LOCK NUTS

The ***Heli-Coil*** Screw-LOCK Insert is adaptable to special-shaped lock nuts, shells, spacers and fasteners and can be engineered to meet your torque or performance requirements. ***Heli-Coil Corporation*** is fully equipped to manufacture these special lock nuts to your specifications.

Note: Custom nuts, with Screw-LOCK Inserts, meet military specifications for lock nuts.

How Design Engineers HELI-COIL* INSERTS to

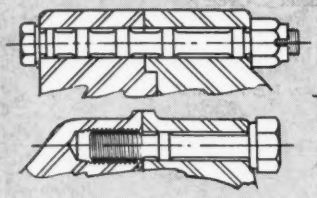
SAVE: SPACE—WEIGHT—COSTS

PERMANENTLY PROTECT THREADS AGAINST

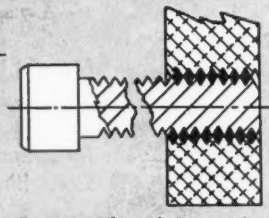
ABUSE • WEAR • CORROSION • STRIPPING • GALLING • SEIZING • VIBRATION

Eliminate Lock Nuts—Lock Wiring—Lock Washers

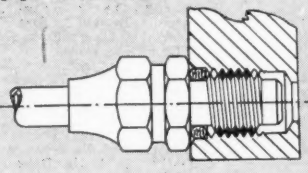
Some Typical *Heli-Coil* Screw-THREAD Applications



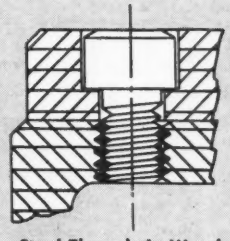
Compact Design
Improves design features by elimination of nuts, washers and extra-length bolts.



Stronger Thread Connections
Under excessive tension, torsion and impact loads in standard proportion bosses, the screw will break but the *Heli-Coil* Screw-THREAD Insert will remain undamaged . . . even in light alloy metal.

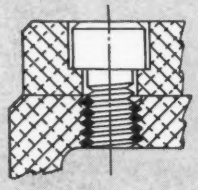


Leak-Proof Connections
In lightweight, high pressure hydraulic equipment, stainless steel inserts, regular and pipe thread, protect threaded pump and valve ports sealed with "O" rings.

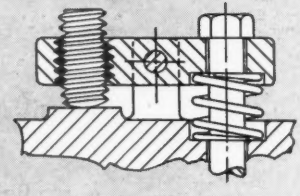


Steel Threads in Wood, Plastics and Fiberglas
Provides permanent, strong, corrosion-resistant and wearproof threads in soft materials. Especially valuable where frequent assembly and disassembly is necessary.

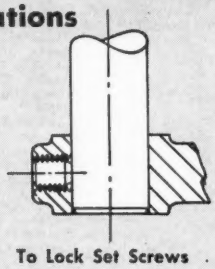
Some Typical *Heli-Coil* Screw-LOCK Applications



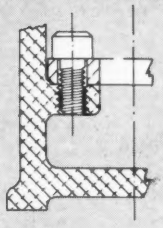
Flush Nut Assemblies
Permits a securely locked, flush assembly, because its internal locking feature eliminates need for drilled head bolts and other protruding locking devices.



Lock Adjustment Screws
This simple design allows permanent, positive adjustment of screws in any position, secure against vibration or impact.



To Lock Set Screws
Positively locks assembly against loosening at desired adjustment—protects threads against stripping under high torque—permits use of light housing materials.



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Heli-Coil Screw-LOCK Insert permits installation of the locking feature from front or top. No blind fumbling for assembly of locking devices inside or behind.

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Sandberg-Serrell Corporation

Carpenter, Herman Jerry, Sr. Engr.
Cockel, Lowell C., Proj. Engr.
Houser, Bradford C., Proj. Engr.
Kenney, James T., Pres.
Morgan, Donald W., Engrg. Dir.
*Serrell, Peter V. H., V-P & Cons. Engr.

Sanders Associates, Inc.

Henderson, Richard B., Proj. Engr.

Sanders Aviation Company

Sanders, Robert, Partner

Sanderson & Porter

Cole, Robert A., Proj. Engr.
Robinson, S. T.
Ross, David H., Engr.
Taylor, Philip B., Partner

Sandia Corporation

Blottner, Frederick G., Staff Mbr.
Breeden, J. S., Staff Mbr.
Bruce, Douglas M., Div. Supvr., Struc. Analysis
Curry, Warren H., Supvr., Engrg. Aerodyn. Div.
Foster, Alfred D., Aero. Engr.
Keeler, William A., Staff Engr.
McAlees, Samuel, Jr., Staff Mbr., Exp. Aerodyn.
Pope, Alan, Hd., Aerodyn. Dept.
Reed, James F., Aerodynamicist
Tate, Roger E., Staff Mbr.
Vaughn, Harold R., Aerodynamicist
Wente, Hermann A., Staff Mbr.

Roy S. Sanford & Company

Eames, J. Owen, Partner & Proj. Engr.

Santa Anita Engineering Company

Bonham, L. D., V-P—Engrg.

Santa Barbara Research Center

Kuhn, Jackson G., Hd., Mech. Devel.

Saunders-Roe, Ltd.

Gouge, Sir Arthur, Vice-Chm. & Ch. Exec.
Maidment, Clifford Tom, Sr. Aerodynamicist
Rosenthal, L. W., Co-ordinating Engr.

Scandinavian Airlines System, Inc.

Romander, Åke Gustav, Ch. Engr.
Romberg, Lars-Georg, Tech. Asst. to Pres.

R. Schasseur, Inc.

Glowe, Albert, V-P

Schrillo Aeronautical Tool Engineering Company

*Schrillo, E. J., Partner

Schweizer Aircraft Corporation

Schweizer, Ernest, Pres. & Ch. Engr.
Schweizer, Paul A., V-P & Gen. Mgr.
Smith, Kenneth F., Proj. Engr.

Scientific Business Programs, Inc.

Israel, Marion S., Pres.

Scott Aviation Corporation

Benzel, Howard A., V-P & Gen. Mgr.
Miller, Arthur E., Ch. Engr.
Scott, Earle M., Pres.

Security Parachute Company

Maggi, John J., Pres.

Seely Instrument Company, Inc.

Patterson, Albert M., Pres.

Service Tool & Engineering Company

Penn, James P., Sales Engr.

Servomechanisms (Canada) Ltd.

Hartley, Croydon H., Pres.

Servomechanisms, Inc.

Carp, James, Sr. Proj. Engr., Western Div.
Gitlin, Robert M., Ch. Mech. Proj. Engr.
Halaby, Najeeb E., V-P—Corp. Devel.
Hansen, Harold S.
Hartley, Croydon H., Foreign Activities Dir.
*Kees, Joseph M., Mgr., Customer Services
Knapp, George P., Ch. Engr.
Larsen, Harold R., V-P & Gen. Mgr., Components Gr.
Lohneiss, William H., Syst. Engr.
Walter, Maurice A., Sr. Proj. Engr.

Sesco Manufacturing, Inc.

Slaymaker, Samuel E., Pres.

Shand & Jurs Company

Wizansky, Dan, Res. Engr., Asst. to Chief of R&D

Shaw Metal Products Corporation

Shaw, Francis, Pres.

Shell Development Company

Cattaneo, Alfred G., Hd., Fuels & Eng. Lubricants Dept.
Gershinowitz, Harold, Pres.

Shell Oil Company

Adamson, Robert M., Mgr., Aviation Dept., West Coast
Bransford, Carroll K., Sr. Engr. Prod. Application Dept.
Culbertson, Albert B., Mgr., Prod. Application Dept.
Doolittle, James H., V-P
Freeman, Julien W., Hd. Ofc. Rep., Aviation Dept.
Hamon, A. J. M., Aviation Mgr., N.Y. Div.
Harris, Darrol N., Spl. Engr.
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Harvey, Hugh, Supvr., Aviation Dept.
Little, Willard S., Jr., Supvr., Tech. Sect., Aviation Dept.
Rohde, Ernst Mues, Asst. Aviation Mgr., Los Angeles
Stewart, Fred M., Aviation Dept. Mgr. Los Angeles Div.
Watson, Frederic R., Sr. Engr., Prod. Application Dept.

Shelly Associates, Inc.

Lilligren, Robert W., V-P—Engrg.
Voigt, Richard A., Des. Engr.

Sheridan-Gray, Inc.

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Shin Meiwa Industry Company, Ltd.

Kikuhara, Shizuo, Ch. Designer, Acft. Div.

Shin-Mitsubishi J.K.K.

Weitner, Walter L., AFPR, Nagoya Acft. Works

Short Brothers & Harland, Ltd.

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Hughes, Cyril Gwynne, Sr. Aerodynamicist, Perf.

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Slocum Publishing Company

Benedict, John T., Engrg. Editor

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Moskovics, Fredrick E., Ind. Cons.
Vickerman, Harold E., Proj. Engr., Aero. Div.

L. B. Smith Aircraft Corporation

Rivera, Armando, A/E Mechanic

Nathaniel Smith Garden Supplies

Smith, Nathaniel

Smith, Winters, Mabuchi, Inc.

Mabuchi, Kenneth Kent, Exec. V-P—Engrg.

Smiths Aircraft Instruments Ltd.

Moss, Eric Beecroft, Tech. Dir.

Snap-Tite, Inc.

Hagger, George F., Ch. Engr.

Snow Aeronautical Company

Snow, Leland, Owner

Société Avialex

Richez, Pierre, Directeur Commercial

Société de Modernisation Industrielle

Beauvais, Robert, Mgr.

Society of Automotive Engineers

Stoner, M. LeRoy, Mgr., Aero. Dept.
Warner, John A. C., Secy. & Gen Mgr.

Socony Mobil Oil Company, Inc.

Heath, D. P.
Miller, Edwin F.
*Mount, Wilbur S., Mgr., Aviation Dept.
Smith, Allen E., Ch. Engr. Aviation Dept.

Solar Aircraft Company

Black, Alexander, V-P—Sales
Clark, Gene W., SW Dist. Mgr., Dallas
Dawson, Paul Louis, Hd., Mech. Sect., Engrg. Analysis Dept.
Grey, Ralph E., Exp. Engr.
Heath, William C., Proj. Mgr.
Klauber, Philip M., Ch. Admin. Engr.
*Kunzel, Herbert, Pres.
Price, Edmund T., Director
Schnaubelt, Norbert C., Supvr., Contract Svc., Des Moines
Stone, Grant B., Sr. Sales Engr.
Woodward, James R., Res. Physicist
Wosika, Leon Rice, Ch., Prelim. Design.

Southeast Airlines, Inc.

Graham, William G., Ch. Pilot

Southern Airways, Inc.

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Southern Bell Telephone & Telegraph Company

Stockstill, Charles J., Jr. Engr.

Southwest Products Company

*Hackman, K. V., Pres.

Southwest Research Institute

Abramson, H. Norman, Mgr., Engrg. Analysis
Epperson, Thomas B., Mgr., Aeroelasticity
Goland, Martin, V-P
Hundere, Al, Chm., Aviation Dept.
Moffitt, John V., Proj. Engr., Ord. Lab. Sect.

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Spartan Air Services, Ltd.

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Casey, John J., Jr., Cons. Engr.
*Speas, R. Dixon, Aviation Cons.

Specialties, Inc.

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Fornoff, Heinz, V-P—Engrg.
McClellan, Stephen A., Pres.
Solarz, Sanford, Publications Mgr.
Thomas, Edward U., Elec. Engr.

Sperry Products, Inc.

Lea, Robert B., Dir. & Cons.

Sperry Rand Corporation

Vickers, Harry F., Pres. & Ch. Exec. Officer

Ford Instrument Company

Coulson, Armand L., V-P—Sales
Goldman, Bernard, Liaison Engr.
Unold, Rodney W., Proj. Supvr.
VanGelder, C. A., Liaison Engr.

Sperry Gyroscope Company

Anderson, E. N., Engr., Hustler Prod. Engrg. Dept.
Andrews, Albert M., Engr.
Beers, Max I., Dir.-Drone & Msl. Engrg.
Berler, Irving, Engrg. Sect. Hd., Spl. Proj.
Bostwick, H. C., Mgr., Aero. Equip. Div.
Brannin, Richard S., Dir. of Res., Aero. Equip. Div.
Brooks, William N., Jr., Engrg. Sect. Hd., Compass Syst.
Brown, Gerald D., Hd., Flt. Res. Dept.
Burdick, Clinton D., Engrg. Sect. Hd.
Carter, Leslie F., Spl. Devel. Engr.
Carver, Leon, Sr. Proj. Engr., Msl. Div.
Clement, Warren F., Sr. Engr., Advanced Devel., Aero. Equip. Div.
Conace, Frank, Sales Mgr., Aero. Equip. Div.
Deutsch, Richard A., Engr.
Falkenstrum, Edward, Field Engrg. Supv.
Fleisig, Ross, Engrg. Sect. Hd., Msl. Guidance
Foster, Jack E., Test Pilot
Fourney, David R., Sales Engr.
Fox, Jack L., Assoc. Engr.
Fragola, Caesar F., Dept. Hd., Instr. Sys
Freymuller, Frederick R., Sales Rep.
Frische, Carl A., Exec. V-P
Ganz, Leonard S., Engr.
Gasper, J. J., Asst. Dist. Mgr., Northwestern Dist. Ofc.
Geller, Edward S., Engr.
Gertz, Arthur P., Dept. Hd., Wpn. Syst. Engrg. Dept.
Gold, Theodore, Sect. Hd., Flight Test & Analysis
Goldberg, Leon, Assoc. Engr.
Greer, Ralph T., Asst. Dist. Mgr., Southwest Dis. Ofc.
Haskell, Nelson J., Sr. Engr.
Hollister, Harold H., Dayton Area Supvr.
*Holschuh, Carl G., Pres. & Gen. Mgr.
Jones, Paul, Engr.
Joseph, Franklin H., Policy & Planning Supvr.
Kaufman, Lawrence, Engrg. Sect. Hd.
Keller, Charles L., Engr.
Kellogg, Spencer, Asst. Ch. Engr., AED
Kimmey, J. W., Sales Svc. Supt.
Kleinman, Joseph M., Tech. Writing Supvr.
Koeppel, Samuel S., Publications Engr., Aero. Equip. Div.
Lange, Donald E., Sect. Hd., Flt. Op.
Lawrence, William L., Field Engr.
Lincoln, David C., Engrg. Dept. Hd.
Lober, George W., Sales Mgr., Microwave–Electronics Div.
Mandel, Merven W., Res. Engr.
Matava, Stephen J., Sr. Engr.
McAtee, William C., Rep., Navigation Syst.
Meisel, Robert M., Engr., Digital Syst.
Neff, LeRoy W., Asst. Field Engrg. Supvr., Seattle
Oestreich, Charles E., Engr.
Oliver, Henry, Engr.
Osder, Stephen S., Engrg. Sect. Hd.
Pantason, Paul, Engr.
Peress, Kenneth E., Engr.
Peters, W. H., Engr.
Petersen, Norman V., Res. Engr., Sunnyvale Devel. Ctr.
Potter, Edwin F., Jr., Flt. Test Engr.
Rouzee, George M., Sales Mgr., Air Armament Div.
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Schlee, Frank, Asst. Engr.
Schleich, Grant W., Sales Rep.
Scolaro, Dominick R., Prod. Methods Engr.
Seels, Henry F., Supt., Aero. Field Svc. Engrg.
Shannon, George M., Jr., Assoc. Engr.
Shapiro, Henry, Sr. Syst. Engr.
Sheehan, William F., Engrg. Sect. Hd., NAMTC, Pt. Mugu
Sheffield, W. B., Engrg Dept. Hd.
Spiegler, Stuart D., Engr.
Staros, Basil, Engrg. Sect. Hd., Syst. Analysis
Steuer, Richard G., Sr. Engr., Fighter Flt. Controls Dept.
Story, Philip C., Engrg. Sect. Hd.
Strihafka, Louis F., Engrg. Sect. Hd.
Swisher, Leon N., Northwestern Dist. Mgr.
Treffeisen, Donal R., Sr. Engr., Res. & Advanced Devel.
Vaccaro, Robert J., Res. Engr.
Warren, Henry W., Rep., Marketing Res. Dept.
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Weckel, Arthur R., V-P
Westerback, Ivar S., Sr. Engr.
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Whittle, Donald A., Field Svc. Engr.
Wiener, Bernard, Flt. Test Engr.
Wies, George A., Sales Rep., Aero. Equip. Div.
Wills, Bruce P., Field Svc. Engr.
Winter, Norman L., Gen. Sales Mgr.
Wright, Gerald B., Sales Mgr., Hustler
Zove, Philip, Engr.
Zupanick, Joseph E., Engrg. Sect. Hd.

Sperry Gyroscope Company of Canada, Ltd.

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Sperry Phoenix Company

Pine, Cecil C., Engrg. Facilities Supvr.
Roe, Robert B., Plant Mgr.

Sperry Utah Engineering Laboratory

Evans, George Dorsey, Engrg. Sect. Hd.
Hylton, J. Carl, Engr.
Mayers, Jean, Sr. Engr., Dept. of Aero. Engrg.
Randell, O. B., Engrg. Dept. Hd.

Wright Machinery Company

Esval, Orland E., V-P & Ch. Engr.

Spiral-Glas Pipe Company

de Ganahl, Carl, Owner

Square D Company

Magin, F. W., Chm. of Bd.

Stainless Steel Products, Inc.

Brant, Donald A., Test Engr.

Stalker Development Company

Clarke, D. J., Ch. Engr.
Stalker, Edward A., Pres. & Gen. Mgr.

Standard Oil Company of California

*Bradley, Richard F., Mgr., Aviation Div.
Wimberly, Donald C., Asst. Mgr., Aviation Div.

Standard Oil Company (Indiana)

*Barnard, Daniel P., IV, Res. Coordinator

Standard-Thomson Corporation

*Aldrin, Col. Edwin E., Eastern Mgr.

Stanford Research Institute

Benedict, Donald L., Dir., Physical Sciences Res.
Bridgeman, Harry M., Mgr., Economics Res.
Ellis, Allen R., Lab. Mgr.
Hayes, George T., Asst. Dir., Physical Sciences Div.
Hutchison, Dale H., Asst. to Dir., Physical Sciences Div.
Kriebel, Anthony R., Mech. Engr.
Low, Lawrence J., Sr. Res. Engr.
Noon, Alonzo William, Sr. Mech. Engr.

Stanford University

Bershader, Daniel, Assoc. Prof. of Aerodyn.
Der, James J., Grad. Stud., Aero. Engrg.
Eustis, Robert H., Assoc. Prof. of Mech. Engrg.
Flügge-Lotz, Irmgard, Lecturer in Engrg. Mech.
Goodier, James N., Prof. of Engrg. Mech.
Gugeler, Robert C., Grad. Stud.
Hoff, Nicholas J., Hd., Div. of Aero. Engrg.
McCuen, Peter Allen, Mech. Engrg. Stud.
Nanevicz, Stanley J., Grad. Stud.
Niles, Alfred S., Prof. of Aero. Engrg.
Reid, Elliott G., Prof. of Aerodyn. Guggenheim Aero. Lab.
Robinson, Eugene Edwards, Grad. Stud.
Vincenti, Walter G., Prof. of Aero. Engrg.

Stanley Aviation Corporation

Arnold, Alison M., Proj. Engr.
Frost, Richard H., V-P
Kuehnegger, Walter, Stress Engr.
Price, R. Allen, V-P—Sales & Svc.
Semler, D. G., Ch. Engr., Acft. Components
*Stanley, Robert M., Pres.

Stanpat Company

Maas, Stanley P. E., Ch. Engr. & Pres.

State College of Washington

Barlow, Howard W., Dir., Inst. of Tech.

Staten Island Community College

Fitzpatrick, James L. G., Prof. & Hd., Dept. of Mech. Tech.

Statham Laboratories, Inc.

DiGiovanni, Mario, Ch. Engr.
Rosa, Gilbert N., Dir., Spl. Proj.
Statham, Louis D., Pres.

The Steel Improvement & Forge Company

McGinty, Douglas, Asst. to Pres.
Smith, Charles H., Jr., Pres.
Zimmerman, H. Arthur, V-P—Sales

Stevens Institute of Technology

Davidson, Kenneth S. M., Dir., Exp. Towing Tank
Hugli, Wilfred C., Jr., Dir., Op. Res. Lab.
Murray, Allan B., Asst. Dir., Exp. Towing Tank
Odenbrett, Clayton L., Res. Engr., Exp. Towing Tank
Savitsky, Daniel, Exp. Towing Tank
Williams, Samuel C., Assoc. Engrg.

Stewart Associates

Stewart, Francis S., Dir.

Stewart-Warner Corporation

Rader, Stan T., Sales Engr.

Stoner Manufacturing Corporation

Phillips, William C., Engr.

Stratford Machine Company

Connelly, J. Fred, Treas.

Strato Engineering Company, Inc.

Craft, Richard D., Stress Engr.
Kaplan, Abraham M., Pres. & Ch. Engr.

Stratoflex of Canada

Preston, Thomas G., V-P & Gen. Mgr.

Strother & Associates

Strother, Ray A., Pres.

Stroukoff Aircraft Corporation

Becker, Eric E., Engr., Struc. Dept.
Ferrara, Caesar L., Sr. Engr., Struc., Vibrations
Frontario, C. A., Q.C. Inspector
King, Capt. John W., USN (Ret.), Asst. to Pres. & Exec. Engr.
Marschner, Walter K., Gr. Engr., Liaison Engrg. Dept.
McDauit, John W., Jr., Sr. Tool Planning Engr.
Moszer, Sidney, Stress Engr.
Rogalski, Stanislaw W., Ch. of Aerodyn.
Seredinsky, Vladimir, Gr. Engr., Aerodyn.
Stowe, Lewis J., Asst. Ch. Engr.
*Stroukoff, Michael, Pres. & Ch. Engr.
Szabo, John R., Jr. Engr.

Structural Fibers, Inc.

Randolph, Donald W., Pres.

Structure Specialties

Brown, Joseph Milroy, Pres.

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LeCarme, Jacques, Test Pilot & Tech. Adviser

James E. P. Sullivan Company

Sullivan, James E. P., Pres. & Owner

Summers Gyroscope Company

Becker, Charles Z., Regional Mgr., Customer Relations Div.
*Brubaker, John W., Chief Engr.
Feltman, Charles H., Jr., Ch., Instr. Devel.
Ford, Birchard, Div. Mgr., Res. Dept.
Light, Edward C., V-P—Mfg. Div.

Sun Oil Company

Liddell, George J., Tech. Asst. to Mgr.

Sunbury Daily Item

Dewart, Lewis

Sundstrand Machine Tool Company

Sundstrand Aviation Division

Camlin, John H., Western Dist. Mgr.
Sadler, Carl L., Gen. Mgr.
St. John, Harry M., Mgr. of Sales

Superior Tube Company

Gabel, S. L., Founder & Mgt. Cons.

Surface Checking Gage Company

Broadston, James A., Ch. Engr.

Surface Combustion Corporation

Hill, J. F., Ch. Engr., Acft. Automotive Div.

Sverdrup & Parcel, Inc.

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Wenzinger, Carl J., Ch., Aero. Dept.

Swedish Air Service Ltd. (Svensk Flygtjanst AB)

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Swedish Turbine Factory Ljungstrom (Svenska Turbinfabriks AB Ljungstrom)

Schnittger, Jan R., Ch. Engr., Gas Turbine Dept.

Swedlow Plastics Company

Tuttle, Orvil S., Pres., Bonded Structures Div.

Swiss Federal Institute of Technology

Amstutz, Eduard, Prof.

Swiss Federal Laboratories for Testing Materials & Research

Amstutz, Eduard, Pres.

Swissair (Swiss Air Transport Company, Ltd.)

Baltensweiler, A. O., V-P—Planning & Res.
Schulthess, Heiner P., Tech. Rep. Douglas Acft. Co.

Sylvania Electric Products, Inc.

Champness, Norman A., Engr. Sr.
Child, E. R., Engrg. Specialist
Hahn, Stuart H., Engrg. Specialist, Electronic Def. Lab.
Hosé, Peter M., Advanced Res. Engr., Msl. Syst. Lab.
Schlieben, Ernest W., Mgr., Devel. Planning, Electronic Syst. Div.

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Dosanjh, Darshan S., Assoc. Prof.
Eskinazi, Salamon, Assoc. Prof., Mech. Engrg.
Torre, Cosimo, Prof.
Werner, Julius M., Asst. Prof.

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Allen, Ralph W., Coordinator, Aero. Syst.
Arthur, Paul D.
*Barnes, John L., Pres.
Walker, Kelsey, Jr., Mbr., Prof. Staff

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Tammen & Denison

DeBrakeleer, Henry J., Sr. Designer

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Ward, Elmer F., Pres.

Taylor Engineering, Inc.

Taylor, Thomas L., Pres.

Tecfab, Inc.

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Hochfeld, Henry, Cons. Engr.

Technical Design & Development Company, Inc.

Strong, Clinton S., Pres.

Technical Development Company

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Schlichting, Hermann, Prof.

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Muftuoglu, O. Saffet, Asst. Prof.

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Isreeli, Jack, Ch. Engr.

Technische Hochschule Aachen

Schultz-Grunow, Fritz

Telecomputing Corporation

Weaver, John H., V-P & Div. Mgr.

Telephonics Corporation

Stengel, J. Frank, Jr., Pres.

Temco Aircraft Corporation

Barnett, Weaver E., Tech. Gr. Engr., Production Projects & Engrg. Loft
Boyd, Donald Stewart, Design
Clark, William S., Admin. Engr.
Collis, Martin E., Jr., Ch., Test & Evaluation
Crane, Richard J., Govt. Sales Rep.
Dunlap, J. J., Jr., Sr. Des. Engr.
Erickson, Donald D., Sr. Liaison Engr.
Frank, M. P., III, Engr., Aerodynamicist
Freeman, William B., Tech. Dir. R&D
Grisham, Norman D., Gr. Engr.
Hawkins, W. Kent, Thermodyn. Gr. Ldr.
Hayes, Roscoe C., Jr., Sr. Engr., Material Review
Hearn, D. L., Ch. Engr., Greenville Plant
Hubbard, Joel R., Sr. Des. Engr.
Jensen, Soren C., Sr. Engr., Aerodynamics
Johnson, Richard H., Sr. Aerodynamicist
Jones, Lynn W., Proj. Engr., Guided Msl. Wpn. Syst.
Lowe, Harold W., Gr. Engr., Flt. Test
Marx, Howard F., Ch., Op. Res.
McKinney, Joe R., Flt. Test Engr.
Mueller, Merle C., Ch. Engr., Garland Div.
Murtaugh, Clyde R., Tech. Specialist, Aerodyn.
Nordyke, S. E., Sr. Engr.
Palley, I. Nevis, V-P—Engrg.
Parker, Paul E., Reliability Control Engr.
Pincha, Elizabeth W., Struc. Engr.
Reynolds, Joe Damon, Sr. Des. Engr.
Ross, William M., Jr., Engr., Aerodynamics
Sawyer, John M., Gr. Engr., Wing Des.
Schoolfield, Daniel R., Engrg. Test Pilot
Smith, Miss Nell, Engr.
Spaulding, Gene B., Dir., Engrg.
Spruill, Cecil E., Gr. Engr., Struc. Methods

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Thalman Aircraft Corporation

Nazir, Phill P., Cons. Engr.

Thermix California, Inc.

Funderburk, James R., Mgr.

Thermix Corporation

Walker, Thomas W., Proj. Engr.

Thieblot Aircraft Company

Gilbert, George W., Designer
Hedgpeth, Harry M., Jr., Proj. Mgr.
Jones, Charles W., Ch. of Mech. Des.
Kindle, Howard, Gr. Des. Engr., Propulsion
Kirby, James R., V-P—Engrg., Wash, D.C.
Matthews, Henry B., Supvr., Prod. Planning
Ridenour, P. J., Jr., Des. Engr.-Checker
Soukhanov, Ivan M., Proj. Stress Engr.
Ward, J. Carlton, Jr., Chm.

Thiokol Chemical Corporation

Blalock, Ralph J., Jr., Asst. Proj. Engr.
*Ferguson, H. R., V-P & Treas.

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Spindell, Philip E., Sales Engr.
Thomas, Kenneth F., Mgr.

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Beremand, Donald G., Proj. Engr.
Chapman, Walter R., Mgr., Devel. Staff R&D New Devices
Chidlaw, Gen. B. W., USAF (Ret.), V-P & Dir.
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*Crawford, F. C., Pres.
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Heller, Jack A., Proj. Engr.
Keresman, Michael A., Jr., Des. Engr.
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McKinnon, R. A., Devel. Engr.
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Glossa, Milton, Liaison Engr. to Ch. Engr.

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Thorp, John W., Owner

F. W. Thorp Services

Thorp, Frank W., Owner

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Lowry, Robert K., Sales Engr.

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Tiburzi, August R., Pres.

Tidewater Oil Company

Frankenfield, C. Walter, Supvr., Automotive Sect., Tech. Svc. Dept.

Tippetts-Abbett-McCarthy Stratton, Engineers

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Titeflex, Inc.

Gunsolus, Ann E., Dir. of Engrg. Publications & Ch. Admin. Engr.

TKM Electric Corporation

Boughton, Warren V., West Coast Factory Engrg. Rep.

Toolko Engineering Company

*Libby, E. J., Owner

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McLucas, John L., V-P

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Pakistan

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Portugal

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Nordling, Olof Vilhelm Tore, Proj. Engr., Royal Swedish Air Bd.
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Thailand

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United Kingdom

Brabazon of Tara, The Rt. Hon. Lord, Chm., Air Registration Bd.
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Jones, Sir Bennett Melvill, Cons. to Dir., RAE
Knell, Kenneth Alfred John, Tech. Asst. to Deputy Dir. Gen. Acft. R&D, MoS
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STATE & MUNICIPAL GOVERNMENTS

Allen, 2nd Lt. William C., Nav. & Observer, Mich. ANG
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U.S. GOVERNMENT

U.S. Air Force

Altus Air Force Base, Okla.

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Andrews Air Force Base, Md.

Horn, Robert P., Acting Ch., Procurement Div., DCS/Material, Hq. MATS
Tucker, Col. John McK., USAF, DCS, Comptroller Hq., Air Wea. Svc., MATS

Ardmore Air Force Base, Okla.

Crandall, Maj. Edmund B., Gr. Material Officer 463d Troop Carrier Gr.
Treneman, 2nd Lt. Thomas William, USAF
Tynan, Charles Irving, Jr., Duty Pilot, 772nd TCS

Arnold Engineering Development Center, Tenn.

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Houston, Capt. Carl Lovett, USAF, Deputy Dir. of Proc., AEDC
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Barksdale Air Force Base, La.

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Bergstrom Air Force Base, Tex.

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Biggs Air Force Base, Tex.

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Brookley Air Force Base, Ala.

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Brooks Air Force Base, Tex.

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Bunker Hill Air Force Base, Ind.

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Carswell Air Force Base, Tex.

Brunsman, Capt. George E., USAF, B-36 Acft. Comdr.

Castle Air Force Base, Calif.

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Chanute Air Force Base, Ill.

Diamant, 2nd Lt. Louis W., USAF, Acft. Maint. Officer
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Newcomb, 2nd Lt. John L., USAF, Maint. Officer

James Connally Air Force Base, Tex.

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Hutchens, Bob J., Pilot, USAF
Mellish, 2nd Lt. Joseph A., USAF

Craig Air Force Base, Ala.

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Davis-Monthan Air Force Base, Ariz.

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Donaldson Air Force Base, S.C.

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Eglin Air Force Base, Fla.

Baxter, Capt. William D., USAF, Air Def. Evaluation Officer, Hq. APGC DCS/O–TR
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Mayo, Capt. Jack B., USAF, Pilot, 3243 Test Gr.
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Rickert, Lt. Col. Walter K., USAF, Ch., Engrg. Br., AF Armament Ctr.
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Skliar, Capt. William L., USAF, Pilot, 3243rd Test Gr., APG Comd.
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Ellington Air Force Base, Tex.

Ball, Capt. John T., Jr., USAF, Stud. Nav.
Bieza, 2nd Lt., Stanley Michael, USAF, Nav.
Grigg, 1st Lt. Fred H., USAF, Nav. Instr.
Mattson, 1st. Lt. Wayne O., USAF, Navigator & Nav. Instr.
Mayben, 2nd Lt. James E., USAF, Stud. Nav.
Oydna, 2nd Lt. Tunney J., USAF

Ent Air Force Base, Colo.

Baker, Kemper W., Ch., Acft. Br., Dir. of Requirements, Hq. ADC
Beckelman, Lt. Col. Jack D., USAF, Ch., Advanced Wpn. Div., Hq. ADC
Bracha, Vincent J., Ch. Proj. Engr., Acft. Maint. Engrg.
Larsen, William A., AC/S, Programming—Programming Officer
Scheuer, James C., Asst. Ch., F-104 Br., Advanced Wpn. Div., Hq. ADC

Ethan Allen Air Force Base, Vt.

Hoover, 2nd Lt. Richard Alan, USAF, Asst. Field Maint. Officer

Fairchild Air Force Base, Wash.

Foss, Capt. Robert N., USAF, 3082nd Aviation Depot Gr., Deep Creek AF Sta.
Gourd, Paul E., Radar Observer
Huggs, Lt. Col. Edward C., USAF, B-52 Maint. Control Officer
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Forbes Air Force Base, Kan.

McAlister, 2nd Lt. Michael J., USAF, Supply Officer, 55th Periodic Maint. Sq.
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Wohlrab, Floyd J., Jr., Supply Div. Supvr.

Foster Air Force Base, Tex.

Fairey, 1st Lt. William G., USAF, Pilot

Geiger Field, Wash.

Windler, Milton L., Pilot, All Wea. Intcp.

Goodfellow Air Force Base, Tex.

Martin, Lt. Donald S., USAF
Smith, 1st Lt. Donald P., USAF, Instr. Pilot, Basic Multi-Eng.

Greenville Air Force Base, Miss.

Napoli, 2nd Lt. Anthony, USAF
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Griffiss Air Force Base, N.Y.

Kaczanowicz, J. W., Proj. Engr. Intelligence Lab., RADC

Hamilton Air Force Base, Calif.

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Harlingen Air Force Base, Tex.

McArthur, 2nd Lt. James W., USAF, Nav.

Ernest Harmon Air Force Base, Newfoundland

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Hickam Air Force Base, Hawaii

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Hill Air Force Base, Utah

Gray, Edwin Eldon, Aero. Engr.
Kale, Capt. Gerald A., USAF, Aero. Engr. & Prod. Engrg. Div.
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Holloman Air Force Base, N.M.

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Deutsch, Lt. Jeffrey S., USAF, Ch., XQ-4 Br., Dir. of Acft. Msl. Test
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Johnston, Capt, Sidney F., Jr., USAF, Pilot & Aero. Engr., Guided Msl., HADC
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Hondo Air Base, Tex.

Perciballi, 2nd Lt. Angelo J., USAF, Student Officer, 3304th Pilot Trng. Gr.

Hunter Air Force Base, Ga.

Crotty, Patrick B., Navigator-Bombardier, 49 B.S.
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Keesler Air Force Base, Miss.

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Kelly Air Force Base, Tex.

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Tracey, Capt. John C., Jr., USAF, Aero. Engr. & Pilot, 1125th F/A Gr.

Kinross Air Force Base, Mich.

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Kirtland Air Force Base, N.M.

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Lackland Air Force Base, Tex.

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Lake Charles Air Force Base, La.

Tiel, Capt. Robert P., USAF, Aero. Repair Br. Officer, 68th Field Maint. Sq.

Langley Air Force Base, Va.

DiCamillo, 1st Lt. Joseph R., USAF, Aero. Res. Scientist, Stability Tunnel, NACA
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Laredo Air Force Base, Tex.

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Shelton, 1st Lt. William E., Jr., USAF, Pilot Instr.

Larson Air Force Base, Wash.

Ernst, Thomas Edward, Maint. Officer

Lockbourne Air Force Base, Ohio

Anderson, Lt. David H., USAF
Scambos, Ernest T., Pilot
Wronski, William R., B-47 Acft. Cdr., 4th Strat. Recon. Sq.

Loring Air Force Base, Me.

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MacDill Air Force Base, Fla.

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Marana Air Base, Ariz.

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March Air Force Base, Calif.

Heffron, 1st. Lt. C. James, Maint. Officer, 2nd Bomb Sq.
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Starch, 1st. Lt. Stephen, USAF

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Model PR-1 Rounds Counter. This 7-oz. unit is designed for instrument panel mounting. *Abrams Instrument Corp.*, 606 E. Shiawassee St., Lansing, Mich.

Type AS Multichannel Sampling Switch. Designed for missile telemetering applications; pressure sealed container allows the switch to operate at altitudes up to 200,000 ft. and in temperatures from 125° down to −65°C. *Applied Science Corp. of Princeton*, Princeton, N.J.

Model E-857 Dual Fire Emergency Safety Switch. This unit is a fire emergency control and fire indicator device for twin-engined aircraft; an interconnect feature restricts the operation of a second control after the first is pulled. *Avionic Products Engineering Corp.*, Rt. 46, Dover, N.J.

L44 "Lo" Mount Vibration Isolators for Air-Borne Equipment. A simplified friction-damping design provides precise control of damping in either or both the vertical and horizontal directions. *Barry Controls Inc.*, 871 Pleasant St., Watertown 72, Mass.

Radar Indicator Recorder for Air-Borne Fire Control System. This camera records range and code lights, as well as radar reading; designed to fit restricted confines of an aircraft cockpit. *Beattie-Coleman Inc.*, 1000 N. Olive St., Anaheim, Calif.

Chemically Inert Gaskets, Back-Up Rings, & "O" Rings. Bulletin P-327 gives complete data on these Teflon units. *Crane Packing Co.*, 6400 Oakton St., Dept. ARN, Morton Grove, Ill.

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Aeronautical Engineering REVIEW

REQUEST FOR PRODUCT INFORMATION

An Official Publication
INSTITUTE OF THE AERONAUTICAL SCIENCES
(Aviation's Professional Engineering Society)
2 E. 64th St., New York 21, N.Y.

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Filters for Aircraft & Missiles. 6-page folder describes latest developments in filtration. *Cuno Engineering Corp.*, S. Vine St., Meriden, Conn.

Hydraulic System Components. 16-page catalog contains engineering data on hydraulic pumps, fluid motors, aircraft-type pumps, and servosystems. *Eastern Industries, Inc.*, 100 Skiff St., Hamden 14, Conn.

Miniature Self-Locking Clinch Nuts. Features a shank design that permits flush installation in stock as thin as 0.030 in. *Elastic Stop Nut Corp. of America*, Union, N.J.

Timing Motors, Timing Devices, & Clock Movements. 30-page catalog describes company's line of timing devices. *Haydon Mfg. Co., Inc.*, Torrington, Conn.

Dynamotor for Guided Missiles. 1,500 series features 100-hour brush life at 50,000 ft. and 500 hours at sea level. Write for bulletin 15F5. *Induction Motors Corp.*, 570 Main St., Westbury, N.Y.

Valves for Aircraft, Missiles, & Rockets. 4-page brochure describes check, relief, shuttle, and shutoff valves. *James, Pond & Clark, Inc.*, 2181 E. Foothill Blvd., Pasadena 8, Calif.

Remote Control Linear Actuator. This actuator enables helicopter pilots to control the tracking of the rotor blades from the cockpit during flight; mounted on the rotor hub. *Lyndon Aircraft, Inc.*, 140-1 Clifford St., Newark, N.J.

MC 1733 Shuttle Valve. Ambient temperature range of this new valve is −65° to +160°F.; operating pressure is 3,000 psi; burst pressure is 8,750 psi minimum. *M. C. Mfg. Co.*, Lake Orion, Mich.

MV-126B Miniature Solenoid Shutoff Valve. Has no moving seals; weighs only $6\frac{1}{2}$ oz. *Marotta Valve Corp.*, 330-1 Boonton Ave., Boonton, N.J.

Hydraulic Servomotors. 24-page booklet includes performance and installation data and photos of 18 different basic servos. *Minneapolis-Honeywell Regulator Co.*, 2600 Ridgway Rd., Minneapolis 13, Minn.

No. 6-6001 Flexible Coupling. Tube crushing at the bead is eliminated; allows a total of $\frac{1}{4}$ in. axial motion and ±30 flexure. *On Mark Couplings*, 200 N. Avenue 64, Los Angeles 43, Calif.

"Nyltite Staps" Controlled-Flow Fastener Seal. For waterproof, vibration-dampening fastening; consists of a self-conforming nylon washer preassembled to a standard self-tapping screw. *Parker-Kalon*, A Div. of General American Transportation Corp., Clifton, N.J.

Model 169 Azimuth Alignment Auto-Theodolite. Designed to monitor inertial guidance systems within 1 sec. of arc. *Perkin-Elmer Corp.*, Norwalk, Conn.

High Output, Low Null Linear Accelerometer. Designed for high performance and rugged environments; null voltages less than 10 millivolts are standard while outputs up to 12 volts can be obtained. *Physical Measurements Corp.*, 1650 Nineteenth St., Santa Monica, Calif.

High-Pressure, High-Temperature Hydraulic Filters. Incorporate stainless steel wire mesh filter elements; will remove all particles above 25 microns in size; can handle fluids up to 400°F. *Purolator Products, Inc.*, Rahway, N.J.

Miniature Inertia Switch. A single moving part, frictionless in operation, momentarily closes electrical contacts, following impact or acceleration above a preset value. *Safe Lighting, Inc.*, 527 Lexington Ave., New York 17, N.Y.

Jet-Engine Vibration Monitor. This device "routinely" picks out and measures selected vibrations within the inner recesses of jet power plants; weighs 15 lbs. *Sperry Gyroscope Co.*, Div. of Sperry Rand Corp., Great Neck, N.Y.

Ballistically Operated Cable Cutter. Triggered by low incoming gas pressure; contains two independently fired cartridges, either of which produces sufficient force to sever a 1/8 in. diameter steel cable. *Stanley Aviation Corp.*, 2500 Dallas St., Denver 8, Colo.

Model S-9 Pressure Transducer. Temperature compensated over the range of −65° to +230°F.; designed for use as the variable inductor in reactance controlled FM/FM subcarrier oscillators. *Ultradyne Engineering Labs., Inc.*, P.O. Box 3308, Albuquerque, N.M.

Miniaturized Hydraulic Components for Missile Applications. Bulletin No. A-5216 describes hydraulic pumps and motors, motorpumps, and miniaturized hydraulic packages. *Vickers Incorporated*, Aero Hydraulics Div., P.O. Box 302, Detroit 32, Mich.

"Quick-Action" Stressed-Panel Fastener. Withstands high shear and tensile loads; locks positively in less than one-half torque-free turn; compensates automatically for sheet separation resulting from warpage or deformation in the panels being secured. *Waldes Kohinoor, Inc.*, 47-16 Austel Place, Long Island City 1, N.Y.

Eyelets, Ferrules, & Terminals. 1957 catalog includes detailed specifications for Waterbury's complete line. *Waterbury Companies, Inc.*, Waterbury 20, Conn.

Adjustable Flareless Union Assembly. For 3,000 psi service in hydraulic and fluid systems requiring a high degree of space utilization. *The Weatherhead Co.*, Aviation Div., 300 E. 131st St., Cleveland, Ohio.

Oil-Filled Gearhead Motor. A two-speed motor designed for 220 V.A.C., 60 cps, 3 phase rated at 1/10 hp. output at 250 r.p.m. and 84 r.p.m.; intermittent duty at high speed, continuous duty at low speed. *Western Gear Corp.*, P.O. Box 182, Lynwood, Calif.

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ELECTRONIC & ELECTRICAL EQUIPMENT

Packaged Relays. Three types of relay are "packaged" into boxes in such a way that the installer need not manufacture his own special mountings, connectors, and protective housings. *Aircraft Radio Corp.*, Boonton, N.J.

Cable-to-Chassis Type Miniature Connectors. Available in 14, 24, 36, and 50 contacts; feature cadmium-plated brass shells with clear chromate treatment, gold-over-silver contacts, and diallyl phthalate dielectrics. *Amphenol Electronics Corp.*, Chicago 50, Ill.

Automatic Control With Miniaturized Nonindicating Meter-Relays. 12-page bulletin 104-A includes complete circuitry information. *Assembly Products, Inc.*, Palm Springs, Calif.

Subminiature Electromagnetic Brake. For electronic and instrument applications; units feature servomounting and high torque capacity. *Autotronics Inc.*, Rt. 1, Box 812, Florissant, Mo.

2N285A High Gain Transistor. Especially useful in feedback circuits to provide superior performance. *Bendix Aviation Corp.*, Red Bank Div., 201 Westwood Ave., Long Branch, N.J.

Subminiature Packaged Crystal Oscillators. Ruggedized for missile and other air-borne applications; dimensions are 1 by $1\frac{1}{2}$ by 4 in. *Bulova Watch Co.*, Electronics Div. P-815, Woodside 77, N.Y.

Rectangular Electrical Connectors. Feature removable "snap-in" contacts which permit attachment to the wires prior to installation in the connector body. *Consolidated Electrodynamics Corp.*, 740 Salem St., Glendale, Calif.

Series 300 High-Speed Sampling Switch. Hermetically sealed; designed for high-altitude applications; up to two poles with 30 nonshorting channels per pole. *General Devices, Inc.*, P.O. Box 253, Princeton, N.J.

Silicon Cartridge Voltage Doubler. Small size, light weight, and rectifying characteristics of these cartridges make them especially applicable to airborne military equipment. *International Rectifier Corp.*, El Segundo, Calif.

500°F. "Ledex" Rotary Solenoid. A life expectancy of 300,000 snap-action operations at 500°F. is claimed; available in eight sizes from 1 to $3\frac{1}{8}$ in. in diameter. *G. H. Leland, Inc.*, 123 Webster St., Dayton 2, Ohio.

Frequency Converter. Makes 400-cycle power available at any 60-cycle electrical outlet; suited for sales demonstrations of aircraft equipment; write for bulletin No. 629. *The Liquidometer Corp.*, Skillman Ave., 36th & 37th Sts., Long Island City 1, N.Y.

"Thermosetting Electrical Tapes." 4-page booklet outlines properties, recommended application procedures, and advantages of "Scotch" brand tapes with thermosetting adhesive. *Minnesota Mining & Mfg. Co.*, 900 Bush St., Dept. D7-207, St. Paul, Minn.

Digital Voltmeters. 28-page booklet describes company's full line of digital voltmeters, digital ohmmeters, a.c-d.c. converters, and complete data logging systems. *Non-Linear Systems, Inc.*, Del Mar Airport, Del Mar, Calif.

Type 8-5001-02 High-Temperature Continuous-Duty Servomotor. For transistorized operations; measures 0.863 L by 0.750 in. OD; weighs 12. oz. *John Oster Mfg. Co.*, Avionic Div., 1 Main St., Racine, Wis.

Style 506 Subminiature Relay. Available in two designs—for critical applications in low-level circuits and for general-purpose use on aircraft and missiles. *Price Electric Corp.*, Frederick, Md.

Electronic Timer Tube. This tiny tube (the size of a cigarette filter tip) shows how long an electronic device has operated. *Raytheon Mfg. Co.*, Waltham 54, Mass.

600 XS-AT Linear Variable Differential Transformer. Has unusually long linear range for its size; a special mechanical design permits flexibility in alignment and a variable distance between mounting points. *Schaevitz Engineering*, P.O. Box 505, Camden 1, N.J.

"Sylvatron" Image-Producing Panels. Consists of flat glass electroluminescent panels with various control layers of photoconductive and electroconductive surfaces; when electrical or optical signals and a power source are applied, a visual display, or image, is produced. *Sylvania Electric Products Inc.*, 1740 Broadway, New York 19, N.Y.

Diffused Silicon Diode/Rectifier. Features 400 mA average rectified forward current plus 600-volt peak inverse voltage ratings. *Texas Instruments Incorporated*, P.O. Box 312, Dallas, Tex.

Corona-Type Voltage Regulators. 8-page paper describes how corona regulators can solve voltage regulation problems without the use of multitube circuits, etc. *The Victoreen Instrument Co.*, 5806 Hough Ave., Cleveland 3, Ohio.

DRAFTING ROOM, PRODUCTION, & MISC. EQUIPMENT

0.2-Micron Vacuum Melting Laboratory Furnace. For titanium, zirconium, vanadium, columbium, tantalum, and other metals that require controlled atmosphere melting. *Oregon Metallurgical Corp.*, Albany, Ore.

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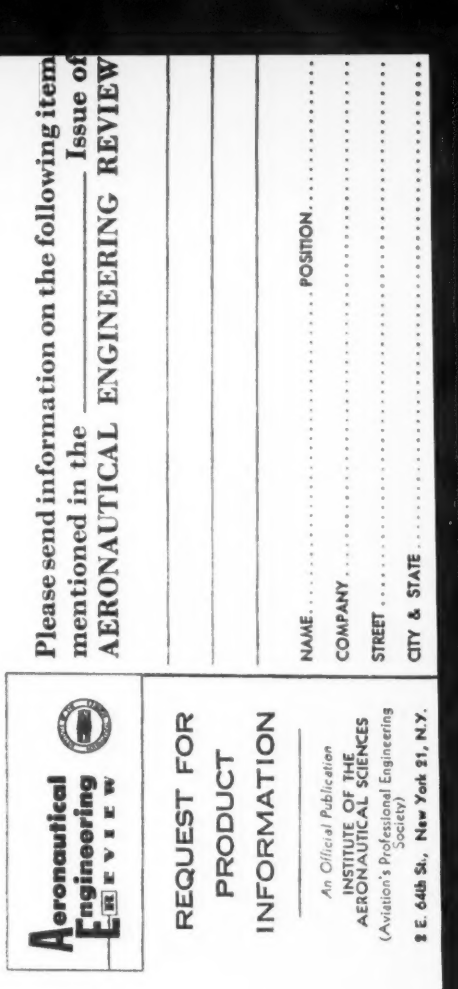
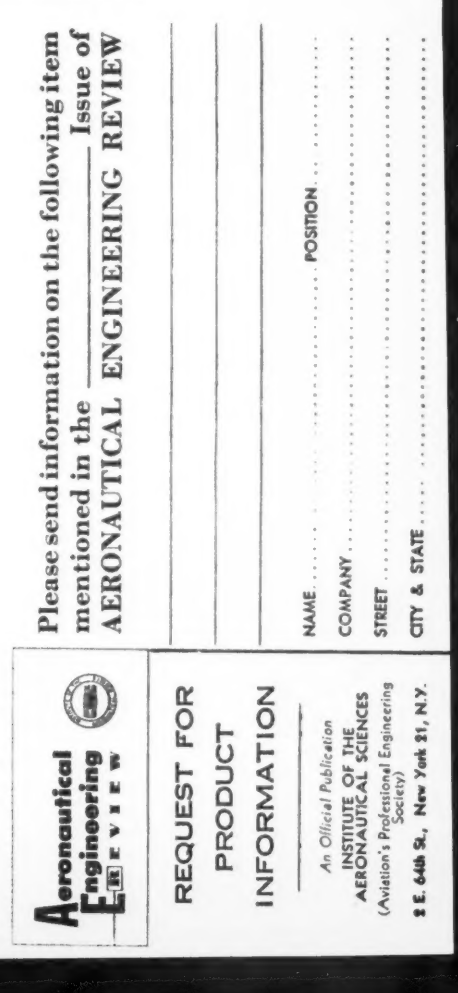

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"A Guide for Selecting an Engineering Firm." Brochure lists specifications to check when seeking an engineering firm. *Teller Co.*, Butler, Pa.

RESEARCH & TEST EQUIPMENT

Model 204 Dynamic Temperature & Strain Recorder. For quantitative measurement of thrust, pressure, and temperature encountered in the solid propellant missile field. *Allegany Instrument Co., Inc.*, 1091 Wills Mountain, Cumberland, Md.

Type K-1 Ballistic Computer. Used in the development of guided missiles; displays and prints seven parameters; contains all necessary equipment for direct hookup to the thrust and pressure transducers. *Allegany Instrument Co., Inc.*, 1091 Wills Mountain, Cumberland, Md.

Type FAB-2 & FAP-2 Foil Type SR-4 Strain Gages. These new gages extend the useful "room temperature" range to 300°F. for continuous duty and 400°F. for short-time measurements. *Baldwin-Lima-Hamilton Corp.*, Electronics & Instrumentation Div., 42 Fourth St., Waltham, Mass.

Module-Type Test Equipment for Gas-Turbine Engine Fuel Controls. This new test stand provides separate areas for the operator and instrumentation, the electrical units, and the fuel handling equipment. *Bendix Aviation Corp.*, Bendix Products Div., South Bend 20, Ind.

Digital & Analog Instrumentation. Short form catalog No. C704 describes 17 new instruments. *Berkeley Div. of Beckman Instruments*, 2200 Wright Ave., Dept. 711, Richmond 3, Calif.

Type 1810 Pulse Calibrator. Technical brochure describes unit designed for accurately measuring current and voltage pulse amplitudes, pulse durations, and rise time. *Burroughs Corp.*, Electronic Instruments Div., 1209 Vine St., Philadelphia, Pa.

Ballistic Film Comparator. Bulletin No. CR-190 describes unit that converts linear distances on film into digital data for automatic recording. *Coleman Engineering Co., Inc.*, 6040 W. Jefferson Blvd., Los Angeles, Calif.

High-Frequency Cathode-Ray Recording Oscillograph. Can record simultaneously up to 16 channels of phenomena at frequencies as high as 100,000 cps on a single 8 in.-wide record. *Consolidated Electrodynamics Corp.*, 300 N. Sierra Madre Villa, Pasadena, Calif.

Type 5-122 Recording Oscillograph. For flight-test recording at high temperatures; operates from −65° to +250°F. at altitudes up to 120,000 ft. *Consolidated Electrodynamics Corp.*, 300 N. Sierra Madre Villa, Pasadena, Calif.

Voice Data Link System. Can convert automatic commands from computing machines into verbal messages; applications include air traffic control, airborne early warning, etc. *Fairchild Camera & Instrument Corp.*, Robbins Lane, Syosset, N.Y.

Small-Case Instruments. Catalog 51-1450 describes Series 1450 line of instruments for indicating, transmitting, and controlling pressure and temperatures; housed in fiberglass cases. *Fischer & Porter Co.*, 212 Jacksonville Road, Hatboro, Pa.

Model GEQ-450 Equameter. This new manually operated computing device performs harmonic analyses and curve fittings on plotted or recorded curves; capable of analyzing a curve in terms of fourier series, power series, or orthogonal polynomials. *The Gerber Scientific Instrument Co.*, 162 State St., Hartford 3, Conn.

"The A-B-C's of Accuracy in Weighing and Force Measurement Systems." A 12-page brochure explains proving rings and their use in force measurement. *Morehouse Machine Co.*, 233 W. Market St., York, Pa.

Model SC-156A Air-Borne - Car-Borne Scintillation Counter. For use in geophysical exploration; features higher count rates, extended detector response, and calibrated zero displacement. *Mount Sopris Instrument Corp.*, 1320 Pearl St., Boulder, Colo.

Manual Range Changing Linear Count Ratemeter. Designed to power and to detect radioactivity sensed by various types of detector. *Nuclear Measurements Corp.*, 2460 N. Arlington Ave., Indianapolis 18, Ind.

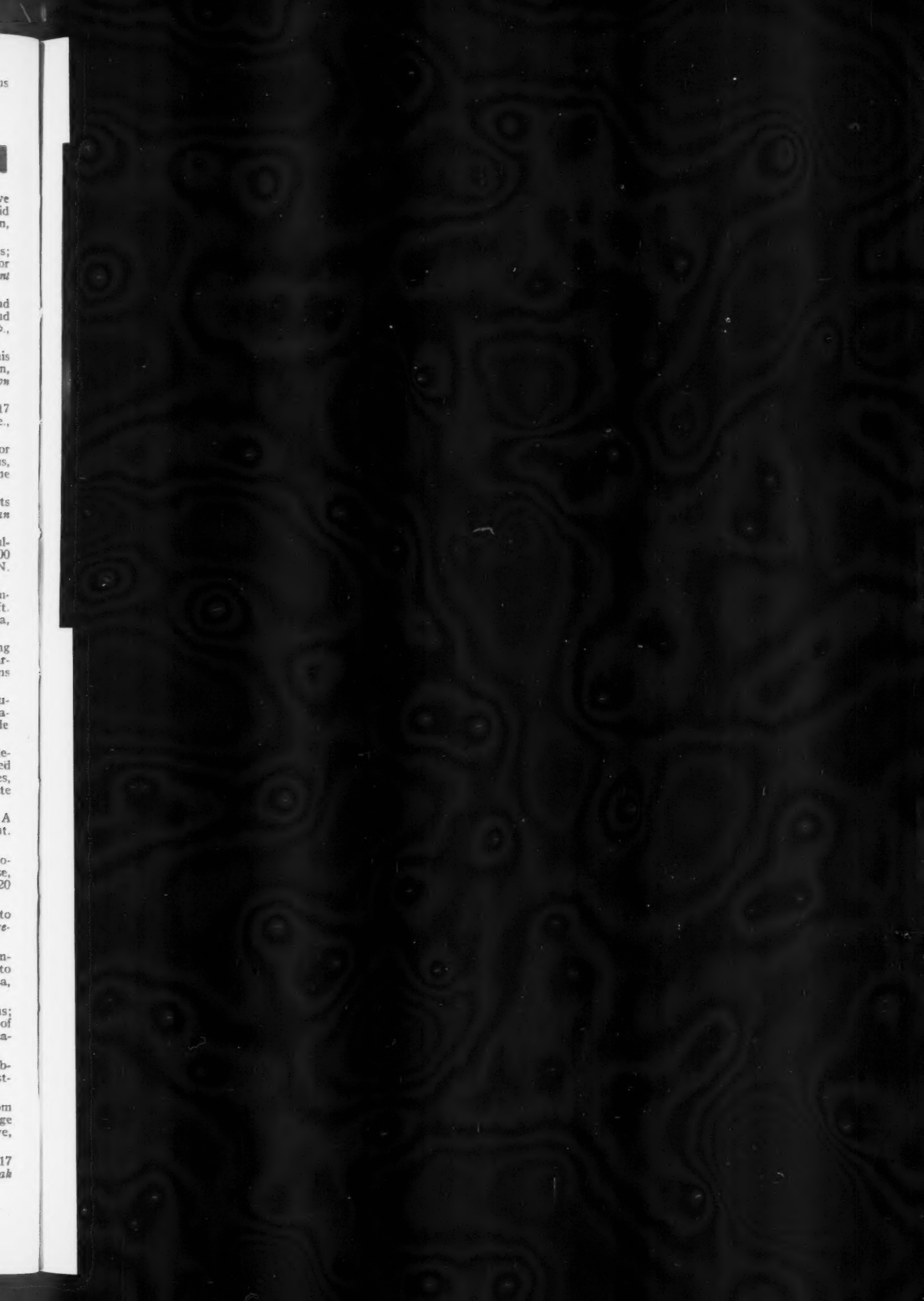
High-Intensity Noise System. Tests the survival capacity of electronic components and assemblies for jets and missiles; simulates in-flight noises up to levels of 145 db. *Radio Corp. of America*, RCA Bldg., 30 Rockefeller Plaza, New York 20, N.Y.

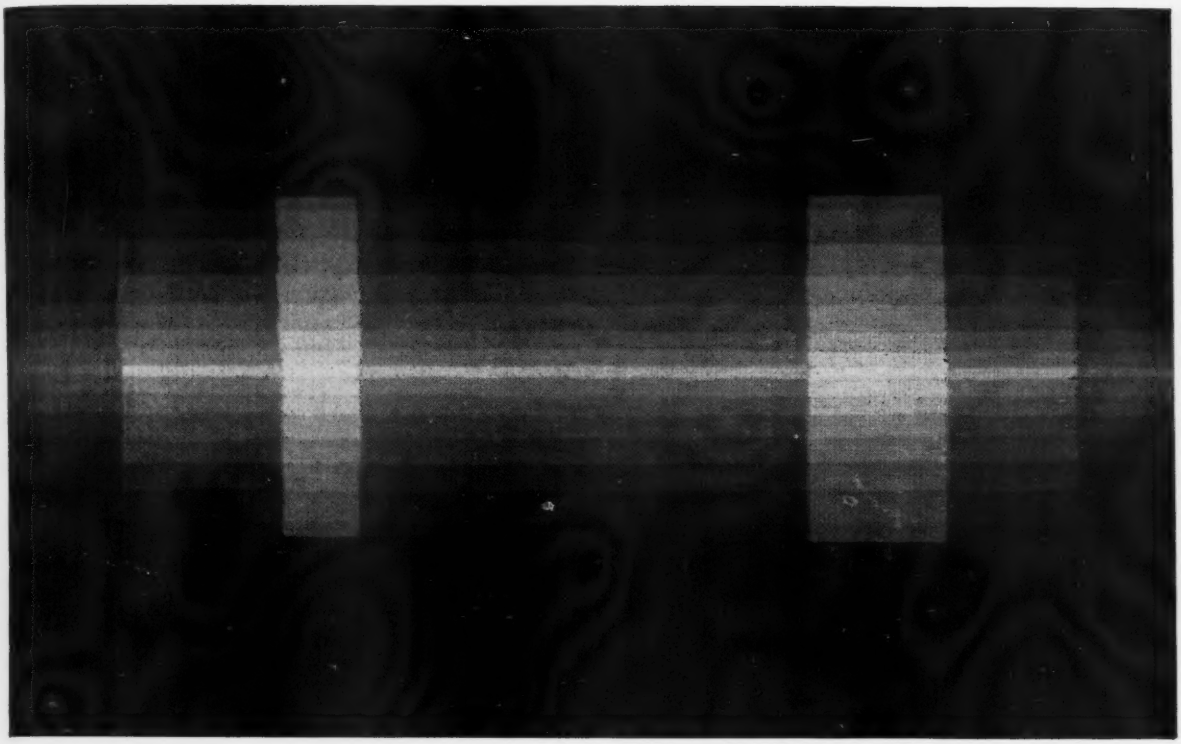
Model 102 Total Temperature Probe. Designed for flight-test applications; features a time constant of less than 25 millisec. under most conditions of operation. *Rosemount Engineering Co.*, 9424 Lyndale Ave., S., Minneapolis 20, Minn.

Resistance Thermometry System. Specifically designed for applications subject to the rigid environmental conditions common to missile and aircraft testing programs. *Arthur C. Ruge Associates, Inc.*, Cambridge, Mass.

Low-Capacity Testing Machines. Available in standard capacities of from 100 to 5,000 lbs.; feature electronic load indication on a large Selectorange dial. *Tinius Olsen Testing Machine Co.*, 7000 Easton Rd., Willow Grove, Pa.

16-mm. Motion Picture Analysis Projector for Missiles. "Fastax" WF-17 records both mechanical and electrical data on the same film. *Wollensak Optical Co.*, Rochester, N.Y.





"STUDY FOR ECLIPSE," a preliminary development by the creative team of Simpson-Middleman, artists whose work is a penetrating expression of the forces and phenomena of the natural sciences. This painting is one of the steps—ground structure—in which the ultimate action will take place. Courtesy of John Heller Gallery, Inc.

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